A B C

AGRICULTURAL COLLEGE BUILDINGS, UNIVERSITY OF WISCONSIN.

A—Horticulture-Physics Building.

B—Central Heating Plant just completed. The two upper floors of this building are used by the Dairy School in its new department of Mechanical Practice, which includes the care and management of creamery boilers and engines, separator installation, factory steam-fitting, soldering, belt lacing, etc.

...(Dairy School Building).

SEVENTEENTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF THE

UNIVERSITY OF WISCONSIN

For the year ending June 30, 1900.

MADISON
DEMOCRAT PRINTING COMPANY, STATE PRINTER
1900

☞ The Bulletins and Annual Reports of this Station are sent free to all residents of the State upon request.

TABLE OF CONTENTS.

LIST OF OFFICERS

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General Offices and Departments of Agricultural Chemistry, Animal Husbandry, Bacteriology, Farmers' Institutes and Library, in Agricultural Hall, near University Hall, on Upper Campus.

Dairy Building and Joint Horticulture-Physics Building, west end of Observatory Hill, adjacent to Horticultural Grounds and Experiment Farm.

Telephone to Station Office, Dairy Building and Farm Office.

LETTER OF TRANSMITTAL.

MILWAUKEE, WIS., NOVEMBER 1st, 1900.

To his Excellency, EDW. SCOFIELD,

Governor of Wisconsin:

I have the honor to transmit to you herewith, in accordance with law, the Seventeenth Annual Report of the Agricultural Experiment Station of the University of Wisconsin.

Respectfully,

GEORGE H. NOYES,

President of the Board of Regents.

REPORT OF THE DIRECTOR.

In presenting this report to the farmers of Wisconsin it is worthy of note that no changes have taken place in the Agricultural Faculty during the year just closed, all workers having remained at their posts prosecuting their investigations or conducting the work of instruction.

It is a great pleasure to the Director to report that through his recommendation the Board of Regents have appointed Doctor S. M. Babcock, so long the Chief Chemist of our Station, to the position of Assistant Director of the Experiment Station. Doctor Babcock's distinguished services have won a world-wide reputation in the dairy field for our state and its university. Most appropriately our last legislature took steps to recognize the services of the doctor by providing that a suitable medal be prepared for him. The dairymen of far-away New Zealand have also recognized his services, and now comes the French government, which through its universal exposition at Paris has awarded to Doctor Babcock a grand prize of honor.

These evidences of appreciation come none too soon, and I am sure all good citizens of our state join with the Director of this Station in wishing to the doctor long life in the enjoyment of his well-earned honors and a continuation of his faithful studies of intricate dairy problems.

A central heating plant.—The Horticulture-Physics and Dairy buildings are situated at the west end of Observatory Hill; Agricultural Hall, originally a dormitory building, on University Hill, is more than a third of a mile distant. It is our purpose to ask the next legislature to provide, in place of Agricultural Hall, a new building to be located in close proximity to

the Dairy and Horticulture-Physics buildings. This accomplished, recitation rooms, laboratories, offices, etc., will all be near together, thereby allowing of the most economical administration, through saving time to teachers, investigators and students.

In anticipation of this final grouping of the agricultural buildings the last legislature was asked for an appropriation to construct a central heating plant, which request was granted. This building is now completed and a view of the same presented in the frontispiece of this report. It is located due north of the Dairy building and west of the Horticulture-Physics building, in close proximity to both. The building covers an area of 40x50 feet, with coal vaults 12x47 feet on the east side. In the basement are placed two 80 h. p. steel low-pressure steam heating boilers and one 50 h. p. high-pressure boiler. Additional room provides boiler space to meet the requirements of the proposed new Agricultural building. Brick-lined tunnels are provided to carry the steam pipes to the several buildings. Over the boiler room is a two-story, white brick building with red brick trimmings, and a red Ludovici terra cotta tile roof. On the first floor of this structure will be placed steam engines, pumps, cream separators, etc., designed for instruction and investigations connected with the operation of creameries and cheese factories. The second floor will be given over to instruction in pipe cutting, soldering, belt-lacing, etc.

East of the Dairy building is located a structure nearly completed at this writing providing additional accommodations for investigation and instruction in cheese making. Rooms are arranged for the manufacture of Swiss and other foreign cheeses, as well as a press room, curing rooms, boxing room, etc. The curing rooms are placed underground in order to secure a more equable temperature. There are several small rooms designed especially for experiments in the proper curing of cheese. A plan of this addition is shown in the present report.

Having provided a central heating plant, the boiler and engine have been removed from the Dairy building and an electric motor substituted for the engine as the motive power. We thereby have much additional room for both experiments and in-

struction. Our plan is to still further enlarge the building so as to include rooms for butter working, pasteurization, cold-storage room and a wash room. The funds for these improvements were kindly provided by the last legislature.

A department for testing new varieties of grains, forage plants, etc.—An experiment station can be of the highest service to farmers in securing and disseminating new and improved varieties of seeds and plants. Our Department of Agriculture at Washington has in recent years inaugurated most important work in this line and several experiment stations in the country are accomplishing great good in the same manner. Years ago the Wisconsin Agricultural College through a worthy citizen secured seed of the Manshury barley, which came originally from Mantchooria, Asia. Having found that this barley yielded more abundantly than ordinary varieties, the seed was extensively grown by the Agricultural College and distributed throughout the Northwest. The dissemination of this one variety of grain was worth millions of dollars to the farmers of the Northwest. If our Agricultural College can find a variety of oats or other grain commonly grown by our farmers which will produce a greater yield by one peck per acre on the average, than the varieties now used, the finding of such a variety would easily return to our state the cost of our whole University.

Heretofore we have done but little work in this direction for the reason that no person connected with the Station had time for its proper prosecution. To be rightly conducted there must be special fields for growing the new varieties of grains and forage plants, and special machinery for threshing the grain, etc. To conduct and supervise the work in its many branches, to make the proper selection of varieties, and finally to distribute the seed wisely over the state, requires the energy of one person with several helpers. While we have not the means to properly carry on this work, we have made a beginning, placing Mr. R. A. Moore in charge of the work. It is hoped that the coming legislature will provide the Station with a sufficient annual allowance to meet the expenses incident to procuring new varieties of seeds and plants, testing the same rapidly and thoroughly, and ultimately distributing the seed of good varieties among the leading

and successful farmers of our state, who in turn will supply seed to their neighbors. Mr. Moore's report of his efforts for the present season as given in pages which follow will certainly prove of much interest to our farmers; let us hope they are the forerunner of an extensive and most useful line of work.

Publications.—During the year ending June 30th, 1900, the Experiment Station issued the following publications:

Bulletin No. 75,	12,000 copies,	30 pages each	360,000 pages
Bulletin No. 76,	18,000 copies,	53 pages each	954,000 pages
Bulletin No. 77,	5,000 copies,	18 pages each	90,000 pages
Bulletin No. 78,	18,000 copies,	16 pages each	288,000 pages
Bulletin No. 79,	40,000 copies,	48 pages each	1,920,000 pages
Bulletin No. 80,	12,000 copies,	39 pages each	468,000 pages
Bulletin No. 81,	10,000 copies,	10 pages each	100,000 pages
Bulletin No. 82,	15,000 copies,	37 pages each	555,000 pages
Bulletin No. 83,	20,000 copies,	68 pages each	1,360,000 pages
2d Ed. B. No. 75,	8,000 copies,	(30) pages each	240,000 pages
Totals ...	158,000 copies,	319 pages	6,335,000 pages
Annual report ...	15,000 copies,	332 pages	5,030,000 pages
Total pages of reports and bulletins			11,365,000

The above shows that during the year there were published by the Station nine bulletins and an annual report, containing in all 651 pages of printed matter, all prepared by the workers of the Station. During the year more than eleven million pages of printed matter in the form of reports and bulletins were distributed from the Station, nearly all going to the farmers of Wisconsin.

Available publications.—Most of our earlier publications are now out of print. We have on hand and will supply to residents of this state only, upon request, until exhausted, any of the following:

Thirteenth Annual Report for the year 1896.
Fourteenth Annual Report for the year 1897.
Fifteenth Annual Report for the year 1898.
Sixteenth Annual Report for the year 1899.

Bulletin No. 29. Creaming Experiments. October, 1891.

Bulletin No. 35. Insects and Diseases Injurious to Cranberries. April, 1893.

Bulletin No. 37. The Russian Thistle. October, 1893.

Bulletin No. 42. Destructive Effects of Winds on Sandy Soils and Light Sandy Loams, with Methods of Protection. October, 1894.

Bulletin No. 43. The Agricultural, Horticultural and Live Stock Features of a Portion of Wisconsin Tributary to Superior, January, 1895.

Bulletin No. 46. Power Tests of Cream Separators. October, 1895.

Bulletin No. 48. The Conn Culture (B 41) in Butter Making. January, 1896.

Bulletin No. 52. A Comparison of the Babcock Test and the Gravimetric Method of Estimating Fat in Skim Milk. The Alkaline Tablet Test of Acidity in Milk or Cream. July, 1896.

Bulletin No. 53. Analyses of Licensed Commercial Fertilizers. July, 1896.

Bulletin No. 54. The Restoration of the Consistency of Pasteurized Cream. August, 1896.

Bulletin No. 55. Beet Sugar Production: Possibilities for a New Industry in Wisconsin. December, 1896.

Bulletin No. 60. The Cheese Industry: Its Development and Possibilities in Wisconsin. May, 1897.

Bulletin No. 61. The Constitution of Milk with Especial Reference to Cheese Production. September, 1897.

Bulletin No. 62. Tainted or Defective Milks: Their Causes and Methods of Prevention. October, 1897.

Bulletin No. 63. The Culture of Native Plums in the Northwest. October, 1897.

Bulletin No. 64. Sugar Beet Investigations in Wisconsin During 1897. January, 1898.

Bulletin No. 71. Sugar Beet Investigations in Wisconsin During 1898. February, 1899.

Bulletin No. 72. Small Fruits in 1898. April, 1899.

Bulletin No. 73. Analyses of Licensed Commercial Fertilizers, 1899. April, 1899.

Bulletin No. 75. Testing Cows at the Farm. October, 1899.

Bulletin No. 76. Noxious Weeds of Wisconsin. July, 1899.

Bulletin No. 77. Effects of the February Freeze of 1899 upon Nurseries and Fruit Plantations in the Northwest. August, 1899.

Bulletin No. 78. The History of a Tuberculous Herd of Cows. August, 1899.

Bulletin No. 79. Principles of Construction and Maintenance of Country Roads. September, 1899.

Bulletin No. 80. The Character and Treatment of Swamp or Humus Soil. January, 1900.

Bulletin No. 81. Analyses of Licensed Commercial Fertilizers, 1900. April, 1900.

Bulletin No. 82. Experiments in Grinding with Small Steel Feed Mills. April, 1900.

Bulletin No. 83. Silage, and the Construction of Modern Silos. May, 1900.

Reports and bulletins wanted.—We have many calls from public libraries and from colleges and experiment stations for copies of former reports and bulletins. The following are out of print and very much desired: Annual Reports of the Agricultural Experiment Station, I and IV; Bulletins of the Agricultural Experiment Station, 1 to 11, inclusive; also 13 and 15.

Friends of the Station who are not keeping files of our publications are earnestly urged to return to us any copies they may have of the rare reports and bulletins. We will gladly pay a reasonable sum for any of the lacking numbers above noted. Readers should bear in mind that the documents asked for are Experiment Station bulletins and reports, and not bulletins of the Farmers' Institute, which is another branch of the Agricultural College.

WHOLE CORN COMPARED WITH CORN MEAL FOR FATTENING SWINE.

W. A. HENRY.

Recognizing that there should be definite information in regard to the relative value of ground and unground corn for fattening swine, the writer began experiments in that line in 1896, and has continued them to the present time. Each year a bunch of hogs has been divided into two equal lots and whole corn given to one lot and corn meal to the other. Records have been kept of the feed consumed, gains made, etc. The trial here reported began December 2, 1899, and ended March 10, 1900, continuing fourteen weeks. One week of preliminary feeding preceded the trial to accustom the animals to their food and to secure normal initial weights; this preliminary week is not included in the data.

The pigs used in this trial were all reared on the University farm. Those in Lot I, numbered 2, 9 and 14, and those in Lot II, numbered 1, 4, 7 and 12, were cross-bred Poland China-Berkshires. All the others were pure-bred Poland Chinas.

To each lot of hogs was fed a ration consisting of two-thirds corn or corn meal and one-third wheat middlings. It was recognized that pigs could not be successfully fed many weeks on corn alone, and we followed our custom of previous years in using wheat middlings as a part of the ration.

The corn used in this experiment was No. 2 Iowa Yellow; that fed previous to January 26, 1900, was found by analysis to contain 11.72 per cent. water; that fed after the above date was corn of the crop of 1899 and contained 14.61 per cent. water.

The corn fed in meal form was reduced by grinding in a buhrstone mill. The meal graded as follows: 1.1 per cent. did

not pass through a screen of 8 meshes to the inch; 2 per cent. passed through a screen of 8 meshes to the inch, but was stopped by a screen of 10 meshes per inch; 38.9 per cent. passed through a screen of 10 meshes per inch, but was stopped by one of 16 meshes per inch; 58 per cent. passed through a screen of 16 meshes per inch.

The grain was fed in the following manner: The corn, either ground or unground, was placed in the trough dry, and soaked middlings placed on top of it. Of such feed the hogs were allowed to consume all they would clean up without waste. In cold weather warm water was used for soaking the feed in order to avoid having frozen material in the troughs. Both lots of pigs received coal ashes, salt and water in liberal supply. The results of the trial are shown in the accompanying tables:

LOT I.—*Fed whole corn and wheat middlings.*

	Feed Eaten, Lbs.		Weight and Gain, Lbs.														Total
	Whole corn.	Shorts.	B* 1	S 2	B 3	B 4	S 5	B 6	S 7	B 8	B 9	B 10	B 11	S 12	B 13	B 14	
Wt. at beginning Dec. 2..	....	....	170	170	134	201	155	192	130	202	185	173	230	136	172	188	2,438
Feed and gain, 1st week..	350	175	12	6	3	8	2	9	7	6	5	9	8	5	11	10	101
Feed and gain, 2d week..	392	196	13	2	13	13	10	14	13	12	12	12	19	12	8	7	160
Feed and gain, 3d week..	392	196	6	12	6	9	8	10	6	10	8	6	9	9	9	5	113
Feed and gain, 4th week.	420	210	15	10	11	9	15	7	8	10	10	12	16	6	13	15	157
Feed and gain, 5th week.	420	210	4	3	8	5	10	10	7	10	10	8	8	6	8	7	104
Feed and gain, 6th week.	420	210	12	4	17	7	12	12	9	4	10	14	12	9	2	6	130
Feed and gain, 7th week.	448	224	13	10	4	6	11	6	12	16	12	8	10	3	15	10	136
Feed and gain, 8th week.	448	224	14	13	10	7	0	11	3	5	14	7	15	11	—1	11	120
Feed and gain, 9th week.	448	224	9	6	6	1	13	9	3	10	9	1	4	8	11	11	103
Feed and gain, 10th week.	448	224	4	4	9	6	19	10	11	11	15	2	8	7	10	12	128
Feed and gain, 11th week.	448	224	0	11	3	1	—6	12	10	9	15	11	11	4	9	10	100
Feed and gain, 12th week.	448	224	20	12	10	5	—1	5	8	12	7	8	3	7	1	16	113
Feed and gain, 13th week.	420	210	1	5	6	14	21	15	12	12	6	7	0	6	11	12	128
Feed and gain, 14th week.	350	175	2	—1	2	—2	—24	—2	0	—6	2	4	2	—4	0	2	—25
Final weight..............	....	....	295	267	242	290	245	320	244	323	320	282	355	225	279	322	4,009
Feed eaten and gains.....	5,852	2,926	125	97	108	89	90	128	114	121	135	109	125	89	107	134	1,571

*B = barrow; S = sow.

LOT II.—*Fed corn meal and wheat middlings.*

	Feed Eaten, Lbs.		Weights and Gains, Lbs.														Total
	Corn meal.	Shorts.	S* 1	S 2	S 3	B 4	S 5	S 6	B 7	B 8	S 9	S 10	B 11	B 12	B 13	B 14	
Wt. at beginning, Dec. 2.	....	....	193	139	169	151	186	172	154	220	122	160	208	170	204	208	2,456
Feed and gain 1st week ..	350	175	8	6	1	9	9	8	6	6	3	2	12	10	11	3	94
Feed and gain 2d week...	406	203	13	7	14	12	14	15	7	14	18	18	28	7	13	18	198
Feed and gain 3rd week..	406	203	16	9	6	8	4	4	10	3	12	11	2	13	7	6	111
Feed and gain 4th week..	448	224	10	9	15	10	15	9	11	15	6	10	12	5	15	14	156
Feed and gain 5th week..	448	224	15	8	7	10	7	16	4	6	5	9	8	7	8	8	118
Feed and gain 6th week..	448	224	3	12	8	7	7	1	4	12	14	10	14	13	12	15	132
Feed and gaid 7th week..	476	238	15	10	10	13	18	13	16	19	6	8	11	14	8	12	173
Feed and gain 8th week..	476	238	22	2	6	12	14	5	6	6	12	15	6	12	13	19	150
Feed and gain 9th week..	476	238	13	6	10	14	15	10	12	14	8	10	15	13	11	12	163
Feed and gain 10th week.	476	238	11	5	14	12	11	6	10	13	14	7	9	12	13	17	154
Feed and gain 11th week.	476	238	22	9	14	19	10	8	10	17	7	8	7	9	10	9	159
Feed and gain 12th week.	476	238	7	−2	9	3	10	17	15	14	−12	9	12	14	10	19	149
Feed and gain 13th week.	448	224	15	10	18	20	5	1	1	12	13	2	3	16	14	15	145
Feed and gain 14th week.	373	187	2	0	−1	2	5	0	4	6	4	1	6	0	7	0	36
Final weights.............	....	....	365	230	300	302	330	285	270	377	256	280	353	315	356	375	4,394
Feed eaten and gains.....	6,183	3,092	172	91	131	151	144	113	116	157	134	120	145	145	152	167	1,938

S = sow; B = barrow.

From these data we learn that

Lot I required 559 pounds of whole corn and middlings (two-thirds shelled corn and one-third middlings) to produce 100 pounds gain in live weight.

Lot II required only 479 pounds of corn meal and middlings (two-thirds corn and one-third middlings) for 100 pounds gain in live weight.

The gains made by Lot I are not particularly economical for the feed required, while those for Lot II are considerably below the average requirements for gain with fattening hogs. Based upon the returns from feeding whole corn and middlings, there was a gain of 15 per cent. in this trial by reducing the corn to meal form. During the first three years of these experiments there was an average saving of 8 per cent. by reducing the shelled corn to meal. Last year, in an experiment with 38 hogs in two equal lots, there was a loss of 2 per cent. by reducing the corn to meal by grinding. It is evident that these trials must be continued longer to reach definite conclusions on this subject of such great importance to the farmers of the corn-growing states.

FEEDING PIGS FOR THE PRODUCTION OF LEAN AND OF FAT MEAT.

W. L. CARLYLE AND A. G. HOPKINS.

There is evidently a growing demand for pork with a much larger percentage of lean meat than has been produced in the past. This is especially apparent in our best foreign markets and is coming to be felt, though not in so great a degree in our home markets. This demand for leaner pork has not been so much appreciated in the United States as in Canada, for the reason that a very large percentage of the fat meat furnished by our hogs has been utilized by the large packing houses in the manufacture of lard, oleomargarine and other products, leaving a larger percentage of lean meat on the market than would otherwise have been the case if the entire carcass had been disposed of as meat. The vital point in the matter from the farmer's standpoint is the effect upon the price obtained for our pork product. The quotations of prices for live hogs on the leading American and Canadian hog markets, viz., Chicago and Toronto, for the past three years have been compiled from the Live-Stock Report, Chicago, and the Farmers' Advocate, London, Can. As seen in the accompanying table the results suggest that the persistent effort put forth by the pork-producing interests in Canada to supply the foreign demand for a leaner pork product has resulted in a much higher price being obtained on both the home and foreign market.

Average of the highest weekly quotations of live hogs on Chicago and Toronto markets for each month of years, 1897, 1898, 1899.

	1897.		1898.		1899.	
	Toronto.	Chicago.	Toronto.	Chicago.	Toronto.	Chicago.
January	$4 15	$3 50	$5 04	$3 77	$4 65	$3 80
February	4 37	3 58	5 03	4 06	4 42	3 90
March	4 87	4 05	5 00	4 07	4 50	3 91
April	5 18	4 10	4 72	4 06	4 65	3 97
May	5 06	3 83	5 04	4 46	4 80	3 92
June	5 25	3 51	5 15	4 09	5 02	3 88
July	5 62	3 71	5 52	4 01	5 02	4 39
August	6 00	4 14	5 95	4 01	5 37	4 74
September	5 83	4 40	4 72	3 99	4 80	4 77
October	5 35	4 01	4 53	3 85	4 52	4 58
November	4 27	3 60	4 32	3 62	4 25	4 12
December	4 61	3 46	4 31	3 51	4 40	4 18
Average for the year	$5 05	$3 82	$4 95	$3 96	$4 70	$4 18
Highest price paid during the year	$6 00	$4 65	$6 00	$4 20	$5 60	$5 00

The report of the British Board of Agriculture for 1898 states that during that year the United States exported to Great Britain of bacon and hams 665,168,000 lbs., receiving an average price of 4.67 cents per pound, while Denmark exported 214,816,000 lbs. and received an average price of 11.37 cents per pound, and Canada exported to Britain 73,136,000 lbs. at an average price of 7.69 cents per pound. There is a striking difference in the prices obtained as shown above in favor of the Danish and Canadian product, and the question naturally arises wherein lies the cause for this marked discrimination against American bacon and hams. In studying this matter with a view of getting at the cause for such a wide variation we found that the leading Canadian pork packing establishments discriminate strongly against all hogs fed on corn, claiming that the feeding of corn to hogs produces a carcass containing a much larger proportion of soft blubbery fat than is the case where feeds such as peas, barley, oats and skim milk, etc., are fed, since these contain a greater percentage of nitrogenous or flesh forming material than

corn. There are also a number of authorities who insist that the percentage of lean meat is more dependent upon the breed and type of hogs fed than upon character of the feed given them.

The object of the investigations of which the experiment here reported is only preliminary, is to determine if possible the controlling factors in the production of a quality of pork that will supply the demands of the foreign trade and will more successfully compete with the Canadian and Danish products in the British markets.

Outline of the experiment.—Sixteen pigs representing three different breeds were chosen for the experiment from four litters of fall pigs. They were all very thrifty and of weights varying from 53 to 84 pounds, averaging 65 lbs. each. Four of the pigs were pure bred Yorkshires, the breed so extensively raised by the Danes and Canadians for the production of their bacon types of hogs. Five of the others were Poland-Chinas and seven were Berkshires all fairly representing these breeds as they are found in the United States.

The pigs were divided into two lots of eight pigs each, care being taken to have the different breeds, litters and large and small pigs divided as nearly equally as possible between the two lots, as shown in the accompanying table:

Data concerning pigs at the beginning of experiment.

LOT I. CORN AND SKIM MILK.

Record number.	Breed.	Number of dam.	Sex.	Age, days.	Weight, lbs.
62	Berkshire	1975	Barrow	70	70
81	Yorkshire	1991	Barrow	107	55
67	Berkshire	1962	Barrow	72	75
87	Yorkshire	1991	Sow	107	56
79	Poland China	1984	Sow	65	65
74	Berkshire	1988	Sow	61	55
72	Berkshire	1988	Barrow	61	60
75	Poland China	1984	Sow	65	84

Data concerning pigs at the beginning of experiment.— Continued.

LOT II. PEAS, MIDDLINGS AND SKIM MILK.

Record number.	Breed.	Number of dam.	Sex.	Age, days.	Weight, lbs.
61	Berkshire	1975	Barrow	70	69
66	Poland China	1992	Barrow	72	70
80	Poland China	1984	Sow	65	60
73	Berkshire	1988	Sow	61	53
82	Yorkshire	1991	Barrow	107	53
83	Yorkshire	1991	Sow	107	72
63	Berkshire	1975	Barrow	70	65
76	Poland China	1984	Sow	61	80

These pigs were fed on a ration composed of shorts, corn meal and skim milk as soon as they would take it and while yet nursing their dams. They were not weaned until the beginning of the experiment on December 16th. During the entire experiment the lots were kept in separate pens provided with clay floors. Each pen was 12 feet square and opened into a yard of the same size. The pigs were well bedded and kept dry at all times, and were given salt and wood ashes frequently during the experiment. One of the Yorkshires (No. 81) in Lot I did not feed well at any time and was taken off the experiment about two weeks before its close when the feed of this lot was decreased one-eighth, as one pig had been taken from the lot of eight.

The pigs in Lot I, bearing the numbers 62, 81, 67, 87, 79, 74, 72 and 75, were fed during the experiment on a ration composed of ground corn and skim milk in equal parts by weight, while the pigs in Lot II, bearing numbers 61, 66, 80, 73, 82, 83, 63 and 76, were fed during the experiment on ground peas and wheat middlings mixed in the proportion of 1 to 1, and an equal weight of skim milk added. The corn was Yellow Dent of good quality. The peas were grown in Northern Wisconsin and were of excellent quality. Both of these grains were ground with a stone mill on the Station farm as needed. The middlings were secured from a local mill, and were somewhat heavier than the commercial grade. The skim milk was from the milk of the Station

herd, it having been passed through a cream separator on the Station farm while yet warm from the cows, consequently it was in prime condition for feeding. The pigs were fed three times each day, one-third of their ration being given them at each feeding period. The different grain feeds were mixed with the milk and allowed to soak and swell for the time intervening between the feeding periods and the pigs were given the amount that both lots would eat readily without waste as it was decided to feed both lots the same amount by weight of the different rations. In future experiments of this kind, one of which is under way at present writing, each pig will be fed in a separate stall and will be supplied with all the feed he will eat readily at each meal, and a careful account will be kept of the amount eaten. Neither of the lots were given any water, as the weather was always cool and they did not appear to care for water to drink.

Discussion of results.—Both lots of pigs made very satisfactory gains, all things considered, though some of them made almost double the gain of others in the same lot. Each pig was weighed individually on Saturday of each week, but in the accompanying tables giving initial and final weights and gains made by each pig the gain is given in two-week periods. For some unaccountable reason there were occasional periods when none of the pigs gained but a very few pounds for a week at a time; this shows somewhat in the two-week periods, but not nearly so marked as in the weekly weighing periods. Grouping the results of each breed separately in the order of their greater gain which, however, was not the object of the experiment, since the feed was not weighed to each one separately, but which grouping is given here as a point of interest and is to be taken for what it is worth, we find the Berkshires ahead with an average gain of 169 pounds each in 126 days, or an average gain per pig of 1.34 pounds per day. The Poland Chinas come next with 153 pounds, or an average daily gain of 1.21 pounds. The Yorkshires made an average gain of 137 pounds, or a daily gain of 1.08 pounds each, leaving out of consideration the Yorkshire pig (No. 81) that did not feed well.

Taking the feeding period as a whole Lot I, fed on ground corn and skim milk, made a more satisfactory gain than did Lot

II, fed on ground peas, middlings and skim milk. The corn-fed (Lot I) gained 70 pounds more in weight during the experiment and ate 135 pounds less of feed than the pea-fed lot, notwithstanding the fact that Lot I was handicapped with pig No. 81, that did not do well for almost the entire experiment.

In looking at the accompanying table we notice that both lots ate practically the same amount of grain, and each lot received the same amount of skim milk per head daily. It will be seen that pig No. 81 was dropped during the last two weeks of the experiment which accounts for the reduction in amount of feed given in columns of corn-fed lot. The pigs in Lot I gained for the whole period of 126 days an average of 158.76 pounds each, or an average daily gain of 1.26 pounds, while the pigs in Lot II made an average gain of 147.75 pounds each, or a daily average gain of 1.17 pounds. This leaves a difference of .09 of a pound of gain per pig daily in favor of the ground corn, which would amount to 2.29 pounds of live weight gain on each 100 pounds of ground corn fed as compared with the same weight of equal parts ground peas and middlings.

Tables showing amount of feed eaten, initial weights aud gains in two-week periods:

LOT I. *Pigs on corn meal and skim milk.*

	Corn	Skim milk.	York. 62 B.	York. 81 B.	Berk. 67 B.	York. 87 S.	P. C. 79 S.	Berk. 74 S.	Berk. 72 S.	P. C. 75 S.	Total wt. aud gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wt. at beginning..	....	360	70	55	75	56	65	55	60	84	520
1st two weeks......	360	352	24	15	25	10	15	20	20	22	151
2d two weeks......	352	312	16	2	19	12	14	11	16	22	112
3d two weeks......	420	420	24	7	28	11	15	10	21	28	144
4th two weeks.....	420	420	18	2	20	16	16	17	19	21	129
5th two weeks.....	420	420	23	6	20	11	20	19	21	18	138
6th two weeks.....	420	420	21	7	13	9	16	11	27	18	122
7th two weeks.....	504	504	24	8	30	20	23	17	15	35	172
8th two weeks.....	560	560	22	8	22	20	25	20	26	20	163
9th two weeks.....	502	502	18	out	20	6	12	18	17	30	121
Total weight and gains.	3,958	3,958	190	55	197	115	156	143	182	214	1,252

B = Barrow; S = Sow.

LOT I. *Pigs on pea meal, shorts and skim milk.*

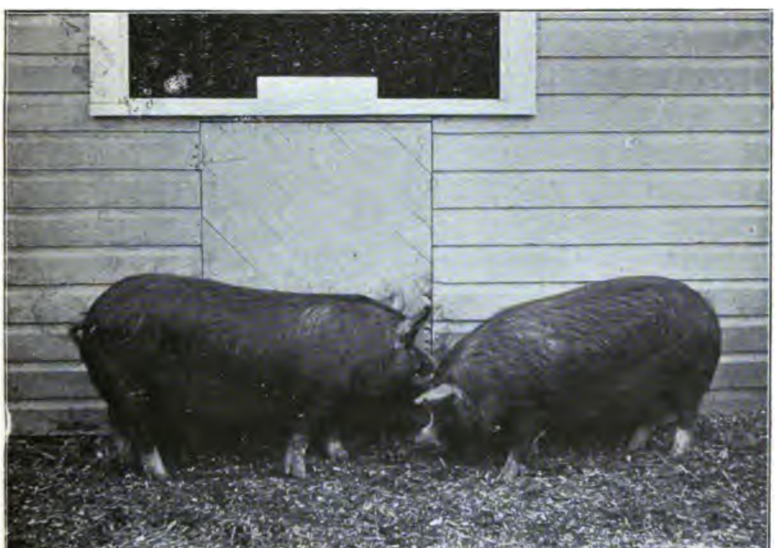
	Pea meal.	Shorts.	Skim milk.	Berk. 61 B.	P. C. 66 B.	P. C. 80 S.	Berk. 73 S.	York. 82 B.	York. 83 S.	Berk. 63 B.	P. C. 76 S.	Total wt. and gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wt. at beginning......	......	......	......	69	70	60	53	53	72	65	80	522
1st two wks.	180	180	360	23	14	18	17	11	19	17	19	138
2d two wks.	176	176	352	20	19	12	10	19	12	15	16	123
3d two wks.	210	210	420	16	12	13	19	15	14	13	11	113
4th two wks	210	210	420	17	22	17	18	20	14	17	11	136
5th two wks.	210	210	420	19	13	14	17	15	14	15	—1	106
6th two wks.	210	210	420	20	8	12	14	17	14	8	—1	81
7th two wks	252	252	504	17	17	22	27	30	23	20	18	190
8th two wks.	280	280	560	16	25	24	17	21	19	20	10	156
9th two wks.	280	280	560	20	17	21	19	19	10	19	12	137
Total weight and gains.	2,008	2,008	4,016	168	147	153	158	167	130	144	95	1,180

B = barrow; S = Sow.

During the early part of the experiment there was no noticeable difference in the appearance of the two lots of pigs, but toward the end it was apparent that the pigs that had been feeding on peas and shorts had a more luxuriant growth of hair than did those from the same litters that had been feeding on a corn diet. It was also noticeable that the corn-fed pigs were not so smooth, having deeper wrinkles in their sides and their flesh appeared more in soft, flabby rolls, especially in the vicinity of their flanks and about the shoulders. The accompanying photographs, taken at the close of the experiment, illustrates fairly clearly these peculiarities in the outward appearance of two pairs of Berkshires and two of Poland Chinas, one pair of each from the corn-fed pigs and one pair each from the pea-fed lot.

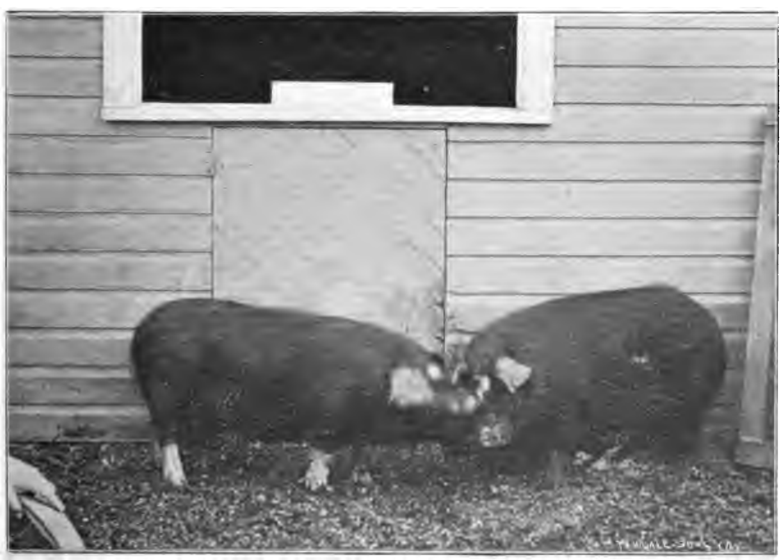
Owing to the limited accommodations in the slaughtering house, etc., only one-half of the pigs on this experiment could be slaughtered at one time, so that a week intervened between the block tests of the Yorkshires and Poland Chinas and those of the Berkshires. They were fasted twenty-five hours in every case before being weighed for slaughter. In dispatching the pigs an

A pair of Berkshire pigs fed corn meal and skim-milk.



A pair of Berkshire pigs fed peas, middlings and skim-milk.

A pair of Poland-China pigs fed corn-meal and skim-milk.



A pair of Poland-China pigs fed peas, middlings and skim-milk.

iron hammer was used to stun them into insensibility, after which they were immediately suspended by the hind legs and were bled from the neck, the blood being received in a large vessel, care being taken to secure all of it. Occasionally a very small sprinkle would be thrown outside of the vessel, but it was so small an amount that it would be almost imperceptible. The length of each pig's body was determined after the carcasses had been scalded. The measurements were taken from the root of the tail to a point in the forehead midway between the eyes. The weights of the various organs of each of the pigs were taken while the carcasses were being dressed, with the exception of the kidneys and the weight of the "leaf lard" or "kidney fat," which was not ascertained until the following day. The length of the small intestines of each pig was determined, as was also the length of the large intestines in a number of instances, which included pigs of each one of the breeds represented in the experiment. These measurements were taken after the intestinal

Summary of feed eaten and gain made by pigs.

	Lot I.	Lot II.
	Lbs.	Lbs.
Average amount of grain eaten per pig per day	3.92	3.94
Average gain of each pig per day	1.26	1.17
Average gain per pig for 126 days	158.76	147.75
Average amount of feed for 100 lbs. gain	632.3	680.6
Amount of digestible protein in 100 lbs. of feed	3.35	8.85
Amount of digestible carbohydrates in 100 lbs. of feed	35.85	28.8
Amount of digestible fat in 100 lbs. of feed	2.3	1.18
Amount of digestible protein for 100 lbs. gain	33.34	60.41
Amount of digestible carbohydrates for 100 lbs. gain	223.41	196.59
Amount of digestible fat for 100 lbs. gain	14.33	8.05
Nutritive ratio	1:7.7	1:3.6

fat had been removed, the method of measuring being similar to that adopted by a dry goods merchant in measuring a piece of cloth on a counter. We found, in attempting to draw the intestines out into a straight line full length upon the floor that it was possible to stretch them quite a distance, in fact, it was

Weight of carcass and various internal organs of pigs fed a ration of peas and shorts in opposition to corn.

LOT I. CORN AND SKIM MILK.

Record number.	Breed.	Gain in 18 weeks.	Live weight.	Dres'd weight.	Per cent. dres'd.	Blood.	Liver.	Kidney	Intestines and stomach.	Length of body.	Length of small intestine.	Length of large intestine.	Intestine fat.	Kidney fat.	Depth of fat over hips.	Depth of fat fat over back.	Depth of fat over shoulders.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Oz.	Lbs.	Inches.	Inches.	Inches.	Lbs.	Lbs.	Inches.	Inches.	Inches.
62	Berkshire.........	190	270	218	80.74	7.1	3.7	6	19 7	43	789	216	6.3	12 5	2 3	2.5	3.7
67	Berkshire.........	197	282	230	81.56	7.	2.9	4	15.8	42	689	180	5.2	13.25	2.3	2.3	2.7
87	Yorkshire........	115	177	131	74.	6.2	....	6	14.	39	758	....	3.	7.	1.3	1.8	2.
79	Poland China....	156	229	180	78.61	5.3	....	5	14.5	41	730	204	3.	8.	2	2.2	2.9
74	Berkshire.........	143	227	187	82 37	6.1	2.7	6	16.7	39	786	174	3.6	7.5	1.7	1 8	2.5
72	Berkshire.........	182	256	207	80.85	6.1	2.7	6	18.7	42	789	....	5.1	11.	2.2	2..	3.
75	Poland China....	214	300	230	79.66	7	....	6	22.	43	784	....	4.3	12.	2.4	2 4	2 8
	Average.........	171	249	197.5	79.6	6.4	3.0	5.6	17.3	41.3	760.7	193.5	4.35	10 18	2.03	2.14	2.8

LOT II. PEAS, MIDDLINGS AND SKIM MILK.

Record number.	Breed.	Gain in 18 weeks.	Live weight.	Dres'd weight.	Per cent. dres'd.	Blood.	Liver.	Kidney	Intestines and stomach.	Length of body.	Length of small intestine.	Length of large intestine.	Intestine fat.	Kidney fat.	Depth of fat over hips.	Depth of fat fat over back.	Depth of fat over shoulders.
80	Poland China....	153	203	151	74.38	5 6	....	6	19.5	38	702	....	3.	7.	1.3	1.8	2.0
76	Poland China....	95	167	128	76.69	7.3	....	5	14.3	34	708	....	2.3	2.5	1.	1 3	1.9
83	Yorkshire........	139	217	171	78.08	8.3	....	7	22.5	40	799	240	3.3	7.	1.5	1.8	1 7
82	Yorkshire........	167	217	160	73.73	8.	....	5	24.	43	720	....	3.	7.25	1.2	1.4	1.8
66	Poland China....	147	225	170	75.55	6.5	5 7	7	20.5	39	741	....	3.7	10.	1.6	1.8	2.5
61	Berkshire.........	168	241	200	82.98	3.8	4.5	6	20.	41	678	180	3.4	8.8	1.5	1.3	1 9
63	Berkshire.........	244	215	178	82.69	5.7	4	5	18.4	39	708	180	5.	10.5	1.5	1.5	2.2
73	Berkshire.........	158	222	191	86.03	7.2	3.9	7	20.	40	802		3.4	7.5	2.	1.5	2.5
	Average.........	146	213	169	78.88	7.17	4.5	6	19.9	39.2	732 2	200	3.4	7.56	1.45	1.55	2.06

impossible not to stretch them more or less even with the method we adopted, but it was found much more accurate than the other way. The thickness of the outer layer of fat along the back was taken after the carcass had been cut through vertically and had been hanging twenty-four hours in the cooling room. One measurement was taken directly over the spinal column between the hips, another just back of the shoulders and the third was taken midway between these two points, or just about the middle of the back.

In studying the findings of the block tests, as given in the accompanying table, we notice that the average percentage of dressed meat to live weight in the pigs of the two lots is practically the same, though very slightly in favor of the corn-fed lot. Comparing the average percentage of dressed carcass to live weights in the pigs of the different breeds represented on the experiment, we find that the Berkshires averages 82.46 per cent., the Poland Chinas 76.97 per cent. and the Yorkshires 75.87 per cent.,—a difference in favor of the Berkshires of 5.5 per cent. over the Poland Chinas and of over 6 per cent. over the Yorkshires. A comparison of the amount of blood found in the pigs of the different lots shows the pea-fed lot to have been 3.37 per cent. of the live weight, and the corn-fed lot to have been 2.51 per cent., which would indicate that the feeding of peas and shorts to pigs would tend to increase the blood content of the body more than if the pigs were fed upon corn.

The livers of the pea-fed lot show a marked increase in weight over the corn-fed lot, which agrees with all previous experiments conducted along this line by this and other Stations. In the kidneys also we find a difference, those of the pea-fed lot being a trifle heavier. The weight of the intestines and the stomachs are also given, but we can attach very little importance to them, since their weight would be greatly influenced by the contents, which would vary greatly. It is noteworthy, however, that the weights given from the pea-fed lot averages over 2.5 pounds heavier than the corn-fed lot. It is evident that the pigs in the corn-fed lot averaged slightly longer in body than did those fed peas, but this must be attributed to the individual peculiarity of the pigs comprising the different lots. In comparing the average length of

the small intestines with the average length of the bodies of the pigs in the differnt lots, we notice that in the lot fed corn the average length of the small intestines is 18.4 times the average length of the body, and in the pea-fed lot they are 18.6 times longer than the average length of their bodies.

The difference in the average amount of fat found upon the intestines and about the kidneys of the different lots is interesting, from the fact that the amount of fat found on these organs is a capital indication of the amount of fatty tissue stored in other parts of the body. In the corn-fed lot we find the average percentage of intestinal fat to dressed weight to be 2.2 per cent. and in the pea-fed lot it is just 2 per cent. This difference is not so pronounced as in the average percentage of kidney fat found in the two lots. Here we find the pea-fed lot amounting to 4.47 per cent. of the dressed weight of the carcass, while it is 5.16 per cent. in the corn-fed lot. The per cent. of water found in the kidney fat and in the fat meat of the back of four of the pigs on the experiment, as shown by the accompanying table, may be of interest. The analyses of these samples were made by the Station chemist, Prof. Woll, on the day following the slaughter of the animals. It will be seen from the table that the fat from the two pigs fed peas and middlings contained a much larger percentage of water than did those fed on corn meal. What effect this may have on the curing and edible properties of the fat meat we are not prepared to say, but it would certainly add to the value of the kidney fat of the pigs from the corn-fed lot over the other for lard rendering purposes. It may be noticed that in the amount of blood, weight of intestines and stomach, weight of livers and weight of kidneys the pea-fed lot has a greater average weight in every case than the corn-fed lot, and as this is generally considered as comprising the most of the material making up the difference between dressed and live weight the question naturally arises as to why there should not be a greater difference than the table shows in the average percentage of dressed meat to live weight between the two lots. This may be explained by stating that in dressing the carcasses of the two lots it was noticed that there was apparently somewhat of a "dropsical" condition in nearly all of the pigs in the corn-fed lot, i. e., there

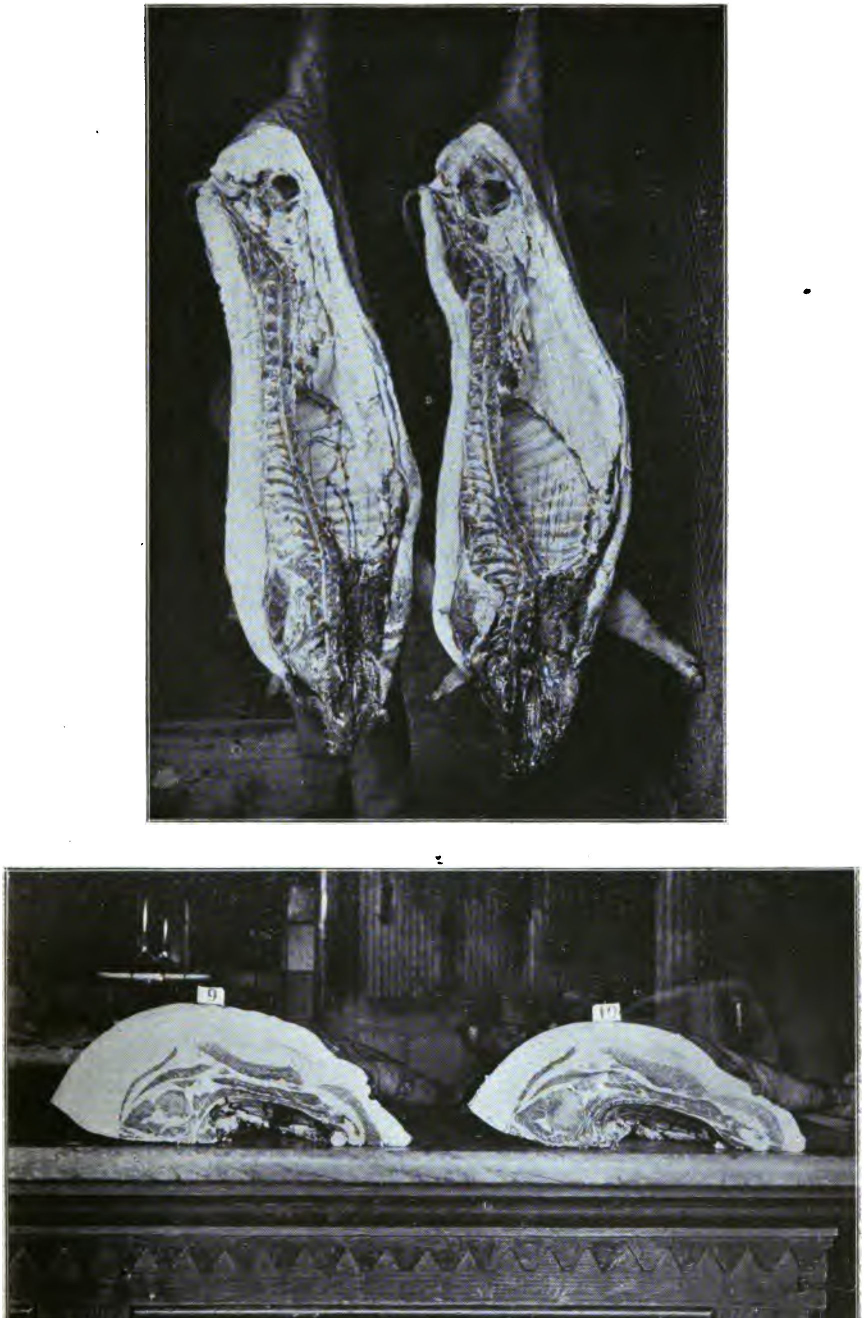


Fig. 5. Showing vertical and cross sections of pure-bred Poland China pigs, litter sisters. Carcass on the left being pig No. 79, fed corn and skim milk, the one on the right, pig No. 76, fed pea meal, shorts and skim milk.

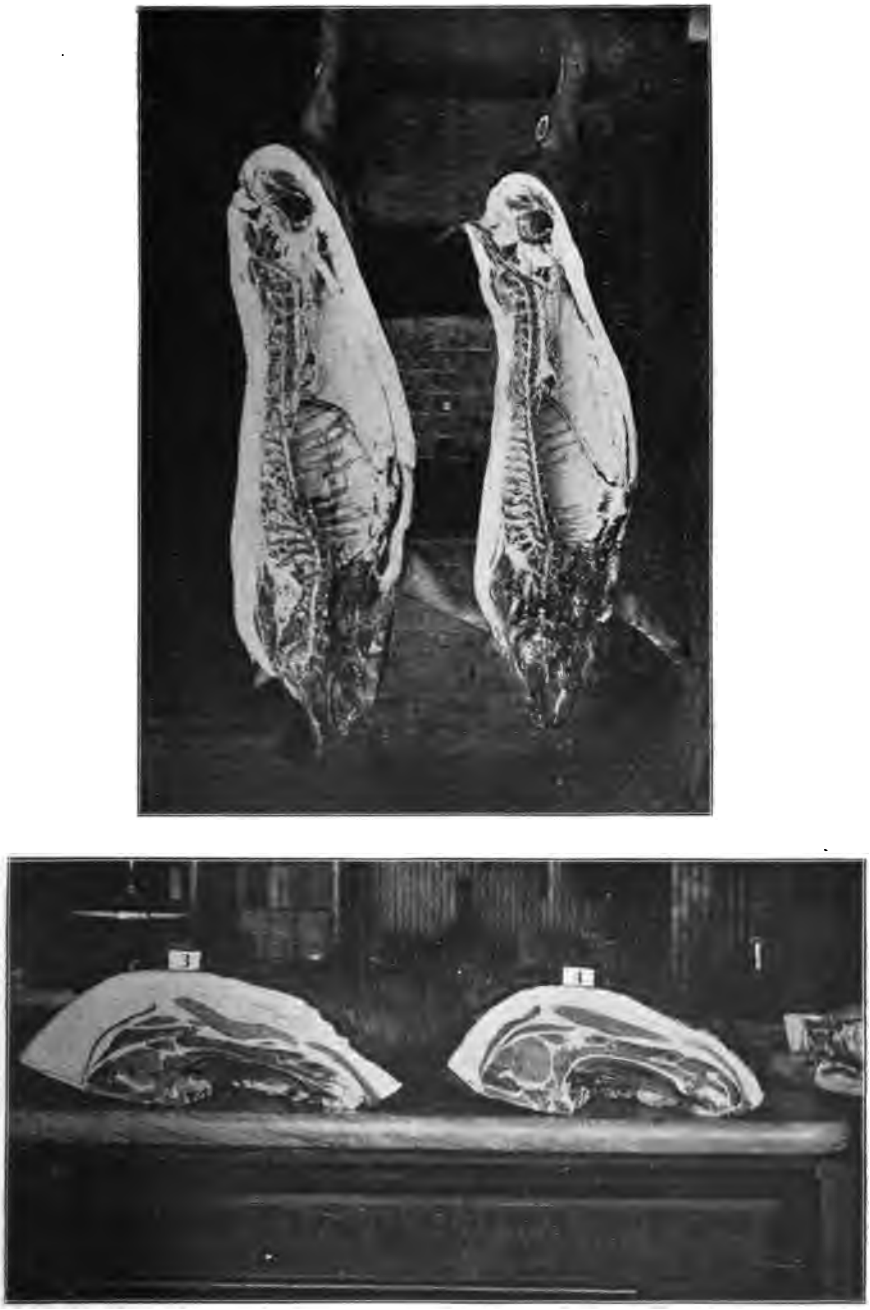


Fig. 6. Showing vertical and cross sections oi a pair of Berkshire pigs. Section on left from pig fed corn meal and skim milk; section on right from pig fed pea meal, shorts and skim milk.

was quite a large quantity of fluid in the abdominal cavity which was not to be found in such quantities, at least in those fed on peas and middlings.

Analysis of fatty tissue of pigs to determine per cent. of water.

Breed	Dressed weight.	Kidney fat weight.	Thickness loin fat.	PER CENT. OF WATER.	
				Kidney fat.	Loin fat.
LOT I.— *Corn meal and skim milk.*	Lbs.	Lbs.	Inches.		
No. 75. Poland China........	230	12.	2.4	2.6	3.82
No. 87. Yorkshire.............	131	7.	1.8	3.15	4.55
Average.....	180.5	9.5	2.1	2.87	4.18
LOT II.— *Ground peas, middlings and skim milk.*					
No. 76. Poland China........	128	2.5	1.3	8.27	7.02
No. 82. Yorkshire.......... ...	160	7.25	1.4	3.71	5.88
Average..........	144	4.87	1.35	5.99	6.45

The accompanying photographs, taken of some of the carcasses of the pigs after they had been cooled, will show quite clearly the marked difference in the amount of fatty matter that was stored up in the tissues of the two lots of hogs.

The carcasses of the pigs were split vertically directly through the spinal column, the photographs showing the spinal cord from end to end. The cross sections show the carcass cut through between the fifth and sixth ribs.

Fig. 5 shows a vertical section of a pair of pure-bred Poland China pigs, litter sisters, the one on the left being a section of pig No. 79, fed on corn meal and milk. Specimen No. 3, just below it, shows a cross section of the same carcass. The vertical section on the right is of pig No. 76, that had been fed pea meal middlings and milk. Specimen No. 4, just below it, shows a cross section.

Fig. 6 shows sections of a pair of Berkshires arranged similar to the preceding, the carcass on the left being from the corn-fed lot and the one on the right from pea-fed lot.

Fig. 7 also shows a pair of Berkshire barrows, litter brothers, very uniform as to size and appearance in every way, except

as to amount of fat carried. The sections on the left from the pig fed corn, and the one on the right from the pig fed peas and middlings.

Fig. 8 shows photograph of a Poland China carcass on the right in the vertical section and of a pure-bred Yorkshire on the left. Specimen No. 2 below is from the Yorkshire carcass, and No. 1 is from the Poland China, however. These pigs were both fed on the corn-meal ration, the photograph being taken and presented here to show the difference in the character of the meat as influenced by breed when the feed remains the same in both cases. We regret that we are unable to present the total amount of grain eaten by these two animals, but hope to do this in all future reports of work of this character.

As stated above, this experiment is simply preliminary to a series we contemplate conducting along this line looking to the solving of many problems concerning the nutrition of pigs.

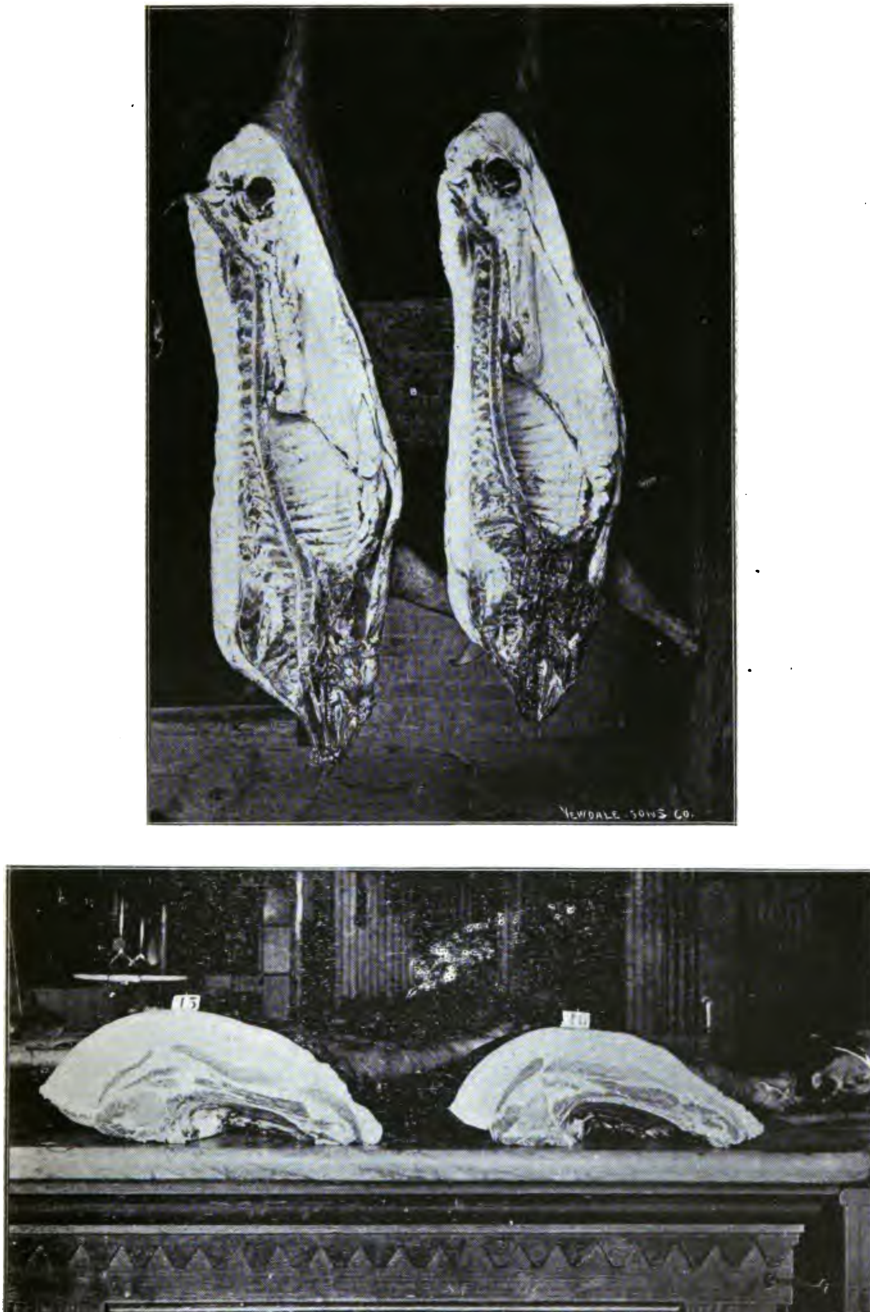


Fig. 7. Showing vertical and cross sections of a pair of Berkshire barrows, litter brothers, very uniform in every way except as to amount of fat. Section on left from pig fed corn, section on right from pig fed peas and shorts.

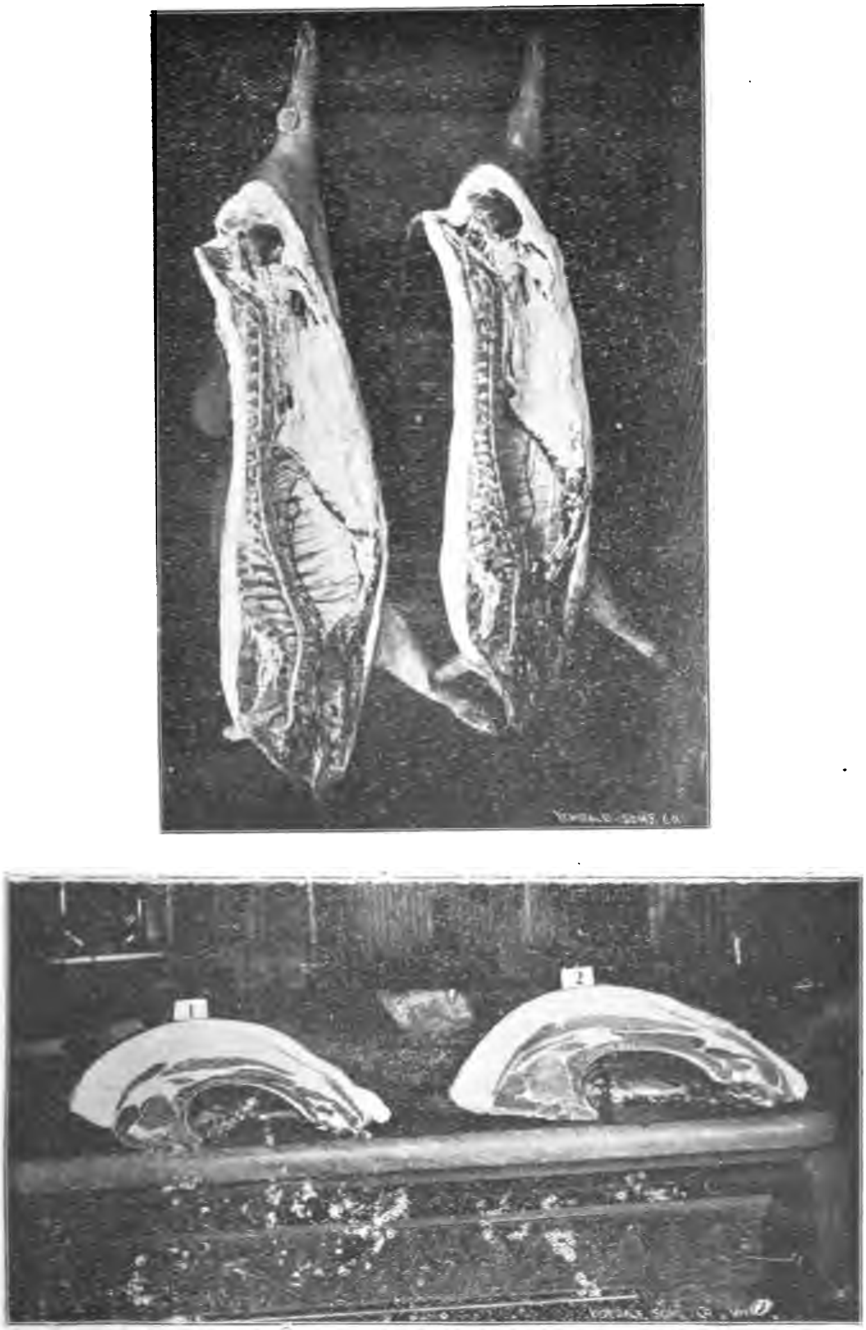


Fig. 8. Showing vertical and cross sections of a Poland-China and a Yorkshire carcass. Vertical section on left is the Yorkshire, and on the right is the Poland-China. Cross section on the left, however, is the Poland-China and on the right is the Yorkshire owing to a mistake in photographing. These pigs were both fed the same feed from birth until slaughtered, the carcasses illustrating very clearly the characteristics of these two breeds.

FEEDING VALUE OF RAPE FOR GROWING PIGS.

W. L. CARLYLE.

Much has been said and written by leading agricultural speakers and writers during recent years as to the feeding value of the rape plant for swine feeding. A great many experiments have also been conducted at a number of the leading experiment stations of this country to determine the value of this plant for the above mentioned purpose, but so far as the writer is aware, all of the experiments reported have been conducted along lines where only a portion of the daily ration was rape, the balance being composed of some of the more concentrated grain foods. Having a number of pigs that were being prepared for a winter feeding trial and about four acres of a second growth of rape that was fresh and tender, such as hogs feed best upon, the writer decided to try exclusive rape feeding for pigs.

Pigs on experiment.—Thirty-six pigs were chosen for the experiment which began the first week of November when the pigs averaged six month of age. They were high grade and pure bred Berkshires and Poland Chinas and were a very thrifty growing lot. Six of them had been in an experiment of eleven weeks duration on exclusive grain diet; eight had been on an experiment where they received grain and clover and the remainder, or twenty-two, had been getting grain and rape.

Conduct of experiment.—The pigs were all turned into the rape for three days, without other feed, after which the initial weighing began on Nov. 7, each pig being weighed separately and the weight recorded. On the following day at the same hour they were again weighed and the average of these two weighings was taken as the initial weight of each pig. The

Table showing gain or loss of pigs fed on rape only.

Numbers of pigs	101	43	33	24	39	100	9	23	21	22	27	13	99	30	44	35	57	20	Total.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Initial weight, Nov. 7 and 8	137	153	152	168	172	196	196	143	156	166	186	211	156	119	157	153	185	170	2,978
Weight November 15	141	156	153	171	169	195	195	143	158	168	187	213	153	112	161	155	180	171	....
Final weight, Nov. 21 and 22	138	153	152	169	168	192	194	140	154	167	183	211	155	121	150	152	181	170	2,950
Gain or loss	+ 1	0	0	+ 1	− 4	− 4	− 2	− 3	− 2	+ 1	− 3	0	− 1	+ 2	− 7	− 3	− 4	0	− 28

Numbers of pigs	42	18	94	15	40	93	59	96	98	51	41	54	12	55	95	17	38	97	Total.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Initial weight, Nov. 7 and 8	160	174	179	133	150	138	128	195	204	120	163	116	188	111	140	166	162	184	2,811
Weight, Nov. 15	160	172	181	136	149	136	126	193	205	120	162	119	188	114	140	170	162	182	....
Final weight, Nov. 21 and 22	155	170	178	131	148	137	124	193	198	122	163	116	184	113	139	170	155	183	2,779
Gain or loss	− 5	− 4	− 1	− 2	− 2	− 1	− 4	− 2	− 6	+ 2	0	0	− 4	+ 2	− 1	+ 4	− 7	− 1	− 32

pigs were not given anything to eat except rape but they had water to drink when they would take it, which was very rarely. They had a clump of very dense evergreen trees to lie under during the day and at night. It was noticed, however, that the pigs were feeding almost all of the time during the day. They appeared very contented, however, never exhibiting any hunger, their stomachs apparently being always distended with food. Contrary to expectations they scoured but little, it may be that the old woody stalks of the rape remaining from the first feeding, and of which the pigs ate freely, aided in keeping the droppings normal as experience teaches that fresh young rape of the first growth without a liberal supply of grain in addition is very apt to scour pigs. The pigs on the experiment were weighed again one week later on November 15 and the final weights of each pig obtained by taking the average of weighings taken on November 21st and 22d. The weather during the experiment was not at all severe, it being mild and pleasant practically all of the time.

Results of the experiment.—The results were somewhat of a surprise since it will be seen from the accompanying table that twenty-five pigs out of the lot of thirty-six lost in weight during the two weeks and only four gained anything. The total loss in weight on thirty-six pigs for two weeks was 60 lbs., or at the rate of one and two-thirds pounds per pig. It is interesting to note that the six pigs that had been fed an exclusive grain diet for eleven weeks immediately before turning into the rape lost a total of 18 pounds or 3 pounds each. The eight pigs that had been fed on a combined ration of grain and clover lost a total of 19 lbs., or a trifle over two and one-third lbs. each, while the twenty-two pigs that had previously been fed on grain and rape lost a total of 33 pounds or one and one-half lbs. each during the two weeks on exclusive rape feeding.

The results of this experiment would indicate that a ration of rape alone fed to pigs for a period of two weeks was not sufficient to supply the food necessary for their support. It is quite possible, however, that it may have a much higher feeding value for pigs at this age when fed in conjunction with grain feed.

THE COMPARATIVE FEEDING VALUE OF CORN FODDER, CORN SILAGE, ROOTS, AND HAY, FOR FEEDING BREEDING EWES IN WINTER.

W. L. CARLYLE.

A great many inquiries have come to this Station during the past few years concerning corn fodder and corn silage as a feed for breeding ewes during winter. Reports have also come to us from time to time indicating that heavy feeding on these substances had resulted unfavorably to the lamb crop. To gather some definite information on this subject a feeding trial was undertaken last winter to determine the comparative feeding value and the effect upon the lamb crop of feeding:

Corn fodder with bran and oats;

Corn fodder and corn silage with bran and oats;

Corn silage and hay with bran and oats;

Roots and hay with bran and oats.

The Station flock of ewes composed of Merinos, Cross-bred Shrop-Merinos, Grade Shrops, Grade and pure-bred Dorsets and pure-bred Southdowns, numbering forty-seven in all, were included in the experiment, which was begun Dec. 29th, and continued for 10 weeks until the ewes began to lamb. Care was exercised in grouping the ewes into four lots, twelve in each of three and eleven in the fourth lot. Ewes of the same age, breed, and size were separated as evenly as possible into the four lots so that each lot would represent as nearly as possible the average ewes of the flock.

The rations fed.—It was decided to give the ewes in the four lots the same kind and amount of grain feed, to consist of .5 of a pound a day for each ewe of bran and oats mixed in equal parts by weight and given in one feed to the different lots. In addition to this the ewes in Lot I were to receive all the cut corn fodder

they would eat, fed night and morning in the feed boxes in the barns, and the refuse weighed back. They were allowed the run of a yard every day where they were fed what they would eat of uncut corn fodder. The ewes in Lot II received corn silage in their feed racks morning and evening and uncut corn-fodder in a yard similar to Lot I. The ewes in Lot III received corn-silage in their feed racks morning and evening and what they would eat of mixed hay in their yard during the day. Those in Lot IV received three pounds each of sliced turnips each day and what they would eat of good mixed hay in their yards. It was planned to give the ewes in Lots I and II four bundles of corn fodder to each lot daily in their yards, while the ewes in lots III and IV were to receive two pounds for each ewe, to be fed in the yards. On weighing a number of the bundles of unhusked corn fodder it was found that they averaged 12.5 pounds each, and after feeding four bundles to each lot daily for a week it was observed that the ewes in these lots were gaining rapidly in weight. Upon husking the ear corn from a number of the bundles the cause of the rapid gains was revealed in the fact that the ear corn husked from the corn fodder averaged 4.4 pounds per bundle, and the twelve ewes in each lot, when receiving four bundles daily, were getting almost 1.5 pounds of ear corn each in addition to their regular grain ration. After the first week all of the corn fodder fed the ewes in Lots I and II in the yards had the ear corn removed so that they received only the stover or the stalks and leaves. The ewes in Lot I ate on the average about 1 pound each per day of cut corn fodder in addition to the stover fed in the yards, while those in Lot II receiving corn silage in the barns and stover in the yards ate an average of almost 3 pounds each per day of corn silage. The ewes in Lot III receiving corn silage in the barns and hay in the yards ate an average of 2.8 pounds of the silage daily, and in addition a trifle over 2 pounds of hay each. The ewes in Lot IV received roots and hay and ate 3 pounds of roots daily and a trifle over 2 pounds of hay for each ewe daily though it was noticed that this lot ate practically all of the hay given them in their yard, while Lot III receiving the corn silage instead of the roots, would not clean it up well in their yard. After the first week it was found necessary to increase the grain ration of bran and oats fed Lot

IV from .5 of a pound for each ewe to .75 of a pound daily, as they were all found to be losing flesh.

Cost of different rations.—The accompanying tables give in detail the amount of the various kinds of feed eaten and the weekly gains or losses in live weight of each of the lots, also the cost of the feed eaten by each lot. In estimating the cost of the feed the following prices were adopted for the different feeding stuffs used:

Bran	$14 00 a ton.
Oats	15 00 a ton.
Hay	5 00 a ton.
Roots	3 00 a ton.
Corn fodder	2 00 a ton.
Corn silage	1 50 a ton.

It will be seen from the data given that the ration fed the ewes in Lot I composed of corn fodder, bran and oats was the cheapest one fed, it costing at prices named .72 of a cent per day to keep each sheep in this lot. The ration made up of corn silage, corn fodder, bran and oats fed to the ewes in Lot II cost .8 of a cent per head daily. The ration fed the ewes in Lot III, consisting of silage, hay, bran and oats, cost 1.03 cents per head daily, while the ration fed ewes in Lot IV, consisting of roots, hay, bran and oats, cost 1.57 cents per head daily, a trifle more than double the cost of the ration of corn fodder, bran and oats fed to Lot I, and almost twice as much as the silage and corn fodder ration fed Lot II.

It may be that the corn fodder is worth more per ton than the value put upon it above, but when it is remembered that the ear corn had been removed from more than one-half of it, the price placed upon it does not appear so low. It is well to observe, however, that while the ewes in Lot II refused only 82 pounds of the corn silage during the experiment, those in Lot I refused 503 pounds of the cut corn fodder fed in the barns, which perhaps should be charged against them, as the ewes in Lot II ate the same kind of corn in the form of silage with a very small proportion of waste.

Tables showing the amount of the different kinds of feed eaten and the amount of gain made by the ewes in each lot.

LOT I.—*12 ewes. Corn fodder, bran and oats.*

DATE.	Grain, oats and bran.	CORN FODDER.				Weight, gain and total cost.
		Cut.			Uncut.	
		Given.	Refused.	Eaten		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec 29	....	....	....	....	....	1,859
Jan. 5	42	192	60	132	140	52
Jan. 12	42	168	68.5	99.5	105	—7
Jan. 19	42	168	43.5	124.5	105	—7
Jan. 26	42	168	41	127	140	23
Feb. 2	42	168	42	126	140	23
Feb. 9	42	168	50	118	175	13
Feb. 16	42	168	49	119	175	15
Feb. 23	42	168	45	123	175	43
Mar. 2	63	168	53	115	175	14
Mar. 9	63	168	51	117	175	28
Total feed and gain	462	1,704	503	1,201	1,505	197
Cost of feed	$3 34	....	....	$1 20	$1 50	$6 04

LOT II.—*12 ewes. Corn silage, corn fodder, bran and oats.*

DATE.	Grain, oats and bran.	CORN SILAGE.			Corn fodder uncut.	Weight, gain and total cost.
		Given.	Refused.	Eaten.		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 29	....	....	....	....	....	1,820
Jan. 5	42	252	16	236	140	50
Jan. 12	42	252	12	240	105	—16
Jan. 19	42	252	1	251	105	—41
Jan. 26	42	252	5	251.5	140	5
Feb. 2	42	252	....	252	140	1
Feb. 9	42	252	2	250	175	29
Feb. 16	42	252	4.5	247.5	175	—4
Feb. 23	42	252	8	244	175	33
Mar. 2	63	252	16	236	175	18
Mar. 9	63	252	22	230	175	15
Total feed and gain	462	2,520	82	2,438	1,505	122
Cost of feed	$3 34	....	....	$1 83	$1 50	$6 67

LOT III.— *12 ewes. Corn silaage, hay bran and oats.*

DATE.	Grain, oats and bran.	CORN SILAGE.			HAY.	Weight, gain and total cost.
		Given.	Refused.	Eaten.	(Mixed.)	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 29	....	... .	....	....	....	1,880
Jan. 5.....	42	252	31	221	168	1
Jan. 12........	42	252	23 5	228.5	168	13
Jan. 19......... ...	42	252	6.75	245.25	168	22
Jan. 26...	42	252	5	247	168	7
Feb. 2....	42	252	1.75	250.25	168	26
Feb. 9............	42	252	7	245	210	18
Feb. 16	42	252	19.5	232.5	210	29
Feb. 23........	42	252	15	237	210	15
Mar. 2	42	252	26 5	225.5	210	83
Mar. 9	42	252	35	217	210	34
Total feed and gain	462	2,520	171	2,349	1,890	154
Cost of feed	$3 34	....	....	$1 76	$1 72	$9 82

LOT IV.— *11 ewes. Roots, hay, bran and oats.*

DATE.	Grain, oats and bran.	ROOTS.			HAY.	Weight, gain and total cost.
		Given.	Refused.	Eaten.	(Mixed.)	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 29............	.. ..	....	....	... .	.. . .	1,778
Jan. 5......... ...	38.5	231	....	231	154	17
Jan. 12........	57.75	231	....	231	154	14
Jan. 19.	57 75	231	.. ..	231	154	11
Jan. 26.	57.75	231	.. ....	231	154	17
Feb. 2.	57.75	231	....	231	154	12
Feb. 9.......	57.75	231	. ...	231	192 5	40
Feb. 16....	57 75	231	... .	231	192.5	1
Feb. 23....	57.75	231	....	231	192 5	30
Mar. 2....	77	231	... .	231	192.5	34
Mar. 9.	77	231	... .	231	192.5	17
Total feed and gain	596.75	2,310	....	2,310	1,732.5	159
Cost of feed.... ..	$4 31	....	....	$3 46	$4 33	$12 10

Effect upon lambs.—Other tables presented herewith give the details of the production of lambs by the different lots, also the weight and condition at birth. It will be seen from these tables that there was not very much difference in the average length of time that the ewes of the different lots carried their lambs. Lots II and III averaged almost exactly the theoretical period of 147 days' pregnancy, while the ewes in Lot I that were fed on corn fodder, bran and oats averaged less than 146 days in pregnancy, and those in Lot IV averaged three-fourths of a day less than the stated 147 days. Nothing of any importance can be gleaned from these slight differences in this respect and the same may be said of a comparison of the number of days in pregnancy of the ewes of different breeds on this experiment. There is also very little that is noteworthy in a comparison of the number or the condition of the lambs produced by the different lots, except the uniformity of increase and general vigor of the lambs from all the flock irrespective of the kinds of feed given the ewes. The 12 ewes in Lot I, fed on corn fodder, bran and oats, gave birth to 18 lambs, averaging in weight 8.37 pounds, all of the lambs coming strong and vigorous but one pair dropped by a young ewe. It was noticed by the Station shepherd, Frank Kleinheinz, who had charge of the sheep during the experiment and later, that the ewes of this lot had less milk in their udders at lambing time than did those of the other three lots. The 12 ewes in Lot II that received corn fodder, silage, bran and oats dropped 19 lambs that averaged 8.05 pounds in weight at birth, and these also were all strong but one lamb which was dropped by a very old ewe. It was noticed that the ewes in this lot had an abundance of milk at lambing time. The 12 ewes in Lot III that had been fed on silage, hay, bran and oats, dropped 22 lambs, averaging 8.14 pounds, but several of them were quite weak and one was dead when dropped. The 11 ewes in Lot IV fed on roots and hay gave birth to 17 lambs that averaged 8.31 pounds at birth and these also were all strong, except one or two.

Tables giving the effects of different rations on the production of lambs.

LOT I.—*Corn fodder, bran and oats.*

No. of ewe.	Breeding.	Due to lamb.	Lambed.	No of lambs.	Weight of lambs	Remarks.
1,532	Grade Shrop.....	Mar. 19	Mar. 19	Single ..	12.6	Strong.
1,951	Grade Dorset.....	Mar. 23	Mar. 19	Single...	9.9	Strong.
1,428	2d Cross Shrop-Merino..	Mar. 21	Mar. 18	Single...	12.4	Strong.
1,858	Southdown... ...	Mar. 17	Mar. 15	Twins ..	7.8—7.4	Strong.
1,860	2d Cross Shrop-Merino	Mar. 28	Mar. 26	Twins ..	8.7—8 0	Strong.
1,940	Grade Shrop. .	Mar. 11	Mar. 9	Twins ..	5.7—8 8	Strong.
1,878	1st Cross Shrop-Merino..	Mar. 11	Barren.	....	....	
294	Merino..	Apr. 16	Apr. 19	Single...	9.3	Strong
1,921	Grade Shrop. ..	Apr 24	Apr. 24	Twins ..	7.1—7.8	Very weak, one died
1,472	Grade Dorset	Mar. 15	Mar. 15	Twins ..	8.4-8.4	Strong.
1,546	Grade Shrop....	Apr. 3	Mar. 31	Triplets.	8.1—7.4—6.2	Strong.
1,878	Grade Dorset.....	Apr. 2	Mar. 31	Single...	11.3	Strong.

LOT II.—*Fed corn fodder, silage, bran and oats.*

No. of ewe.	Breeding.	Due to lamb.	Lambed.	No. of lambs.	Weight of lambs.	Remarks.
1,516	Grade Shrop..	Mar. 15	Mar. 16	Twins ..	8.8—6.3	Strong.
1,852	1st Cross Shrop-Merino..	Mar. 21	Mar. 21	Twins ..	7.8—7.2	Strong.
1,827	Grade Dorset.....	Mar. 23	Mar. 29	Single ..	9.6	Weakly.
1,867	Grade Dorset... .	Mar. 15	Mar. 15	Twins ..	7.7—6.8	Strong.
1,468	2d Cross Shrop-Merino...... ...	Apr. 3	Apr. 3	Twins ..	9.3—9.0	Strong.
1,907	3d Cross, Shrop-Merino..........	Apr. 16	Apr. 15	Twins ..	5.9—6 7	Fairly strong.
1,909	Grade Shrop.....	....	Barren.	....	....	
1,427	Grade Shrop.. ..	Mar. 22	Mar. 19	Twins ..	6 7—7 2	Small but strong.
1,469	Southdown.......	Mar. 24	Mar. 23	Single ..	9.2	Strong.
1,455	Grade Shrop.....	Mar. 20	Mar. 18	Twins ..	9 5—6.4	
7,645	Pure bred Dorset.	Mar. 25	Mar 26	Twins ..	10.5—8.0	Strong.
334	Merino..........	Apr. 8	Apr. 7	Single ..	10.5	Strong.

LOT III.—*Fed corn silage, hay, bran and oats.*

No. of ewe.	Breeding.	Due to lamb.	Lambed.	No. of lambs.	Weight of lambs	Remarks.
1,902	Grade Shrop....	Mar. 27	Mar. 25	Twins ..	7.0—5.4	Strong but small.
1,418	Grade Shrop......	Apr. 15	Apr. 17	Single ..	9.3	Strong.
1,914	Grade Shrop..	Mar. 23	Mar. 25	Twins ..	8.4—7.0	Strong.
1,036	Grade Dorset.....	Mar. 12	Mar. 13	Twins ..	9.8—8.5	Strong.
1,007	Grade Dorset.....	Mar. 18	Mar. 19	Twins ..	11 8—8 0	One strong, other born dead.
1,911	Grade Shrop	Mar. 29	Mar. 26	Twins ..	7.2—6.1	One strong, other weak.
1,827	Grade Shrop.. ..	Mar. 15	Mar. 13	Twins ..	8.4—8 1	Strong.
1,863	Grade Dorset.. .	Mar. 8	Mar. 11	Single .	9.6	Weak.
293	Merino...	Mar. 27	Mar. 29	Single ..	9 2	Strong.
1,859	Southdown.......	Mar 1	Mar. 14	Twins ..	10.4—7.7	One strong, one weak.
1,831	Grade Shrop......	Mar. 27	Mar. 25	Triplets.	8.9—6.1—5 7	Fairly strong.
1,870	Grade Dorset. ...	Mar. 12	Mar. 11	Twins ..	8.0 -8.7	Strong.

LOT IV.—*Fed roots, hay, bran and oats.*

No. of ewe.	Breeding.	Due to lamb.	Lambed.	No. of lambs.	Weight of lambs.	Remarks.
1,568	Grade Shrop..... .	Mar. 27	Mar. 29	Single ..	8.7	Strong.
1,925	Grade Shrop.....	Apr. 3	Apr. 5	Twins ..	7.4—7.7	Fairly strong.
1,554	Grade Shrop	Mar. 16	Mar. 16	Twins .	10.2—8.5	Strong
1,451	Grade Dorset.....	Mar. 14	Mar. 12	Triplets.	10.—8.7—7.2	Two strong, one weak.
1,823	3rd Cross Shrop-Merino...... .	Mar. 29	Mar. 29	Twins ..	9 2—6.9	Strong.
1,918	3rd Cross Shrop-Merino	Apr. 10	Apr. 7	Single ..	8.9	Strong.
1,832	Grade Shrop.. ...	Apr. 2	Mar. 30	Twins .	9.3 8.8	Strong.
1,328	Grade Dorset......	Mar. 28	Mar. 23	Single ..	7.1	Strong.
1,333	Southdown.......	....	Barren.	....	....	
1,951	Grade Dorset....	Mar. 13	Mar. 14	Twins ..	7.1—6.3	One strong, other died at birth.
1,920	Grade Shrop.....	Mar. 17	Mar. 17	Single ..	9.3	Weak.

Summary of results.—In so far as this experiment goes it indicates that well cured corn fodder, of which about 65 per cent. has had the ear corn removed, when fed to breeding ewes during winter, in conjunction with .5 of a pound of an equal mixture of bran and oats to each sheep, is a very cheap and entirely satisfactory feed ration. Also that corn silage fed in conjunction with either corn fodder or mixed hay and the same ration of bran and oats is a very satisfactory and very cheap ration for winter breeding ewes that are pregnant. This experiment would also seem to indicate that hay and roots are a very expensive feed ration for wintering breeding ewes and that they do not give any better results than the other and cheaper rations fed. It would appear also that corn fodder containing a large proportion of ears should not be fed largely to breeding ewes until the ear corn had been removed, as well cured and unhusked corn fodder may have fully fifty per cent. of its weight in the ear corn, and the ewes might readily get too much ear corn and become too fat. A study of the tables on page 31 giving amount of feed consumed by Lots I and II, and cost of same, will reveal the fact that the ewes in these two lots ate exactly the same amount of grain and of uncut corn stover and fodder, and that Lot I ate 1,201 pounds of cut corn fodder and gained 197 pounds in ten weeks, while the same number of ewes in Lot II ate 2,438 pounds of corn silage and gained 122 pounds in the same length of time. Assuming for the sake of comparison that all the gain in live weight on the ewes in Lot I was made from the corn fodder and that all the gain in weight on the ewes in Lot II was made from the corn silage, which is quite fair, since all the other feed was the same in kind and amount, we find that 20 pounds of corn silage were required for one pound of gain in Lot II, while but 6 pounds of corn fodder were required for the same amount of live weight gain in Lot I. It is expected to continue this experiment for some years until some positive and definite results have been obtained.

ON THE ECONOMY OF HEAVY GRAIN-FEEDING OF DAIRY COWS.

F. W. WOLL AND W. L. CARLYLE.

The experiment reported in the following pages is a continuation of an investigation commenced in 1898 and reported in our last annual report (pages 56–67). The object of the investigation is to ascertain how much grain, or grain feeds, can be fed to dairy cows with economy; in other words, whether the feeding of large quantities of grain gives so much better returns than those obtained with moderate quantities as to be an economical practice. By reference to the account of last year's experiment in our Sixteenth Annual Report it will be seen that the heavy grain-feeding (12 pounds of mixed grain daily per head) in no case proved economical as compared with a medium grain ration of 8 pounds per head daily, the feed of the cows being, in addition, made up of a small allowance of hay, and of silage fed *ad libitum*. As this result is not in conformity with the practice of many observing dairymen, who in general feed grain heavily to their cows, it was decided to repeat the experment during the past winter.

The plan of the experiment here reported was essentially the same as the one followed last year, as regards the conduct and duration of the experiment, and the handling of the cows. It was varied as to the number of animals included on the experiment, which was sixteen, instead of eight that completed the experiment last year. The method of feeding the cows was also changed, in so far as it was planned this year to feed as the normal grain ration the amount of grain which, according to careful observations and trials, was required by each animal for maintaining a good flow of milk and a constant

live weight. As a result the daily allowance of grain varied greatly with the individual cows, viz., from 4 to 10 pounds per head. The allowance was increased by 50 per cent. in each case with the cows of Lot A during the second period of the experiment, while the cows on the control lot (Lot B) were fed the same amounts of grain throughout the three periods of the experiment. In addition to the grain fed, the cows received a small allowance of hay (4 pounds a day per head), and corn silage *ad libitum.*

Cows on the experiment.—The cows included on the experiment were selected from our University herd and represented the following breeds of cattle: Jersey, Guernsey, Holstein-Friesian, and Shorthorn. The Shorthorns were represented by five grades and two pure-bred animals, the Holsteins by two pure-bred animals, while all the Jersey and Guernsey cows on the experiment were high-grades. The cows in our University herd are kept for dairy purposes and have been selected as types of the various dairy breeds (the dairy type of Shorthorns is represented in the cows kept of this breed). For this reason the cows available for experimental purposes vary considerably in their characteristics as to size, feeding capacity, quantity and quality of milk and products, etc. There are both advantages and disadvantages in having such varying types of animals on an experiment of this kind. The main advantage lies in the fact that the results obtained with such animals have more general value than if only one or two of the specific dairy breeds were represented on the experiment; the disadvantage comes in the difficulty in arranging a limited number of such animals in two uniform groups that may be supposed to respond to the same system of feeding and handling in a like manner.

The sixteen cows selected for the experiment were separated into two groups as uniform as possible as to breed, age, days in milk, time of next calving, live weight, amount of grain to be fed, and the yield of milk and butter fat. The followng table gives data on these points for each cow at the beginning of the experiment and shows the grouping of the cows in Lots A and B.

Data concerning cows at beginning of the experiment.

Name of cow.	Breed.	Age.	Days in milk.	Days before calving	Live weight Jan. 1.	Normal grain per day.	Milk, Dec. 25-Jan. 1.	Fat, Dec. 25–Jan. 1.	
								Yield.	Per cent.
LOT A.		Years.			Lbs.	Lbs.	Lbs.	Lbs.	
Duchess........	Sh.	9	58	323	1182	10	166.9	7.68	4.6
Pauline.........	Sh.	5	146	318	1265	4	138.1	5.66	4.1
Alma	*H.-F.	3	139	255	865	10	221.5	7.31	3.5
Dora	G.	4	92	212	1043	8	193.9	8.92	4.6
Murphy.........	J.	6	36	310	912	8	206.3	11.97	5.8
Bessie...........	G.	7	78	292	790	8	156.5	8.92	5.7
Princess.........	Sh.	2	20	339	980	7	216.3	9.95	4.6
Nan..............	J.	4	4	399	818	9	192.5	10.02	5.2
Average.....		**5**	**72**	**306**	**982**	**8**	**26.7**	**1.26**	**4.7**
LOT B.									
Jane.............	*Sh.	10	82	291	1020	10	203 5	7.73	3.8
Rose.............	Sh.	6	284	164	1150	7	155.3	8.70	5.6
Maud............	Sh.	5	115	350	1053	8	184.6	6.83	3.7
Chloe...........	*H.-F.	3	182	254	1180	8	161.0	5.47	3.4
Dollie...........	G.	4	59	303	1018	6	170.3	10.22	6 0
Lizzie.	G.	8	42	323	955	8	228.2	10.73	4.7
Goodrich........	J.	4	72	316	730	10	164.3	8.22	5.0
Campbell.......	*Sh.	6	24	342	1120	7	223.2	9.37	4.2
Average......		**5.75**	**108**	**294**	**1028**	**8**	**26.6**	**1.20**	**4.5**

* Pure-bred cows.

Seven of the cows included in this year's experiment were on the experiment last year.

Plan of the experiment.—The experiment commenced on January 1, 1900; it was divided into three periods of four weeks each; the first week of each period was considered preliminary, the purpose being to accustom the animals in Lot A to the changes in feed; the data obtained during these weeks have not been included in the summaries. The cows in Lot A received their normal allowance of grain during periods I and III, viz., on the average, eight pounds per head daily (see preceding table); during period II, as stated above, the amounts fed to each cow were increased by 50 per cent., the average allowance

for this lot therefore being 12 pounds per head daily during this period. The cows in Lot B received an average of 8 pounds per head daily during the three periods of the experiment, as will be seen in above table. In addition all cows were given 4 pounds of hay each day and as much corn silage as they would eat without waste. The grain fed was in all cases mixtures of wheat bran, ground oats, ground corn, and oil meal (O. P.), in the proportions of 2:2:1:1.

The corn silage fed was from well-matured Pride of the North corn having a fairly large proportion of ears. The amount of grain contained in 50 pounds of silage was determined accurately every week and was found to correspond to very nearly two pounds of dry corn per head daily, on the average. The quality of the silage was good and the cows ate it with great relish.

The hay was timothy and clover, about 75 per cent. being timothy. It was of rather poor quality, and the cows did not seem to eat it readily. The oats were of good quality and were ground in small quantities as desired for feeding. The corn, grown in Iowa, was of splendid quality; it was finely ground with a stone grinder as needed. The oil meal and wheat bran were purchased in bulk in Minnesota and were exceptionally good; the former feed was old-process meal, and the latter roller bran.

The chemical composition of the feeding stuffs used on the experiment, as analyzed by one of us (W.), is shown in the following table:

Chemical analyses of feeding stuffs.—In per cent.

	Moisture.	Ash.	Crude protein.	Crude fiber.	N-free extract.	Ether extract.	Total nitrogen.	Amid nitrogen.	Per ct. amide nitrogen.
Corn silage.....	69.09	1.66	2.61	6.48	19.13	1.03	1.35	.30	22.2
Mixed hay......	12.31	5.75	8.55	33.83	38.16	1.40	1.56	.16	10.3
Oats......... ..	12.52	3.44	11.05	10.60	57.80	4.59	2.02	.13	6.4
Corn............	14.87	1.77	8.73	1.94	69.31	3.38	1.64	.16	9.8
Wheat bran ...	13.05	5.87	15.16	10.75	50.87	4.30	2.79	.29	10.4
Oil meal, O. P..	11.67	5.45	33.90	7.38	35.79	5.81	6.14	1.06	17.3

The acidity of the corn silage was determined each week during the experiment; the following average contents were obtained: Lactic acid, 1.64 per cent.; acetic acid, .60 per cent.

The digestible components of the feeding stuffs are given in the following table. The percentages have been calculated from the average digestion co-efficients for the various feeding stuffs given by Jordan and Hall in their recently published compilation, "The Digestibility of American Feeding Stuffs."*

Digestible components of feeding stuffs.—In per cent.

	Crude protein.	Carbohydrates.	Fat.
Corn silage	1.46	19.03	.84
Mixed hay	4.02	41.58	.73
Oats	7.96	45.05	3.76
Corn	5.94	64.46	3.11
Wheat bran	11.83	38.22	2.92
Oil meal, O. P	30.17	32.13	5.05

Conduct of experiment.—The cows were milked at 4:30 A. M., each day. They were fed silage at 5:45 A. M., one-half of the daily grain ration being fed with the silage. The stables were then cleaned. At 8 A. M. the cows were watered in their stalls, the amount of water drank by each cow being determined by weighing on Mondays and Tuesdays of each week of the experiment. Weighings of the cows were made on the days mentioned, immediately before watering.

The cows were fed their allowance of hay at 9:30 A. M.; they were again watered at 3:30 P. M., and the stables cleaned. The milking in the afternoon was begun at the same hour as in the morning, viz., at 4:30, and finished at 5:30. Silage with the remaining portion of the grain was then fed as in the morning. The details of the conduct of the experiment will be seen from the directions furnished the herdsman, which are here reproduced:

* Bull. 79, Office of Experiment Stations.

DIRECTIONS FOR CONDUCT OF COW-FEEDING EXPERIMENTS, JANUARY TO MARCH, 1900.

Cows.—The cows on the experiment are:

Lot A, Duchess, Pauline, Alma, Dora, Murphy, Bessie, Princess, Nan.

Lot B, Jane, Rose, Maude, Chloe, Dollie, Lizzie, Goodrich, Campbell.

Feed.—Mix thoroughly the following kinds of feed: Fifty pounds bran, 50 pounds oats, 25 pounds ground corn and 25 pounds of oil meal. Weigh out as many pounds of this mixed feed per cow as recorded in the barn record book. Half of the grain feed is fed in the morning and the other half in the evening.

In addition feed 4 pounds of hay daily in the forenoon, and give the cows all the corn silage they want in the evening and in the morning.

Refuse Feed.—Clean out feed troughs in the morning and afternoon each day before watering, and weigh back the amount of refuse feed.

Salt.—Place salt in the boxes and keep a record of amount eaten. All cows on the experiment receive salt except Nan and Rose.

Weight of Cows.—The cows will be weighed Monday and Tuesday of each week immediately before watering.

Watering.—The cows are watered twice a day: first, in the morning directly after milking and feeding silage, and second, in the afternoon before milking and feeding. The weight of the water drank by each cow is determined on the days when the cows are weighed. Note temperature of water once each week.

Milking and Sampling.—The milking will begin at 4:30 A. M. and 4:30 P. M. sharp, the cows being milked in the same order and by the same milker each time. This is very important, and if for any reason these directions are not followed a note should be made of the fact in the barn record book.

Each cow's milk is weighed and sampled separately immediately after milking, two-thirds of a pint being taken for a sample of each milking. Record the weight of milk on the milk sheet, and also on the gummed label on the bottle in which the sample was placed.

Temperature Records.—The stable temperature is to be read off three times a day, at 5 A. M., noon, and 6 P. M., and recorded on the temperature sheet hung in the stable.

Keeping Records.—Copy all figures in the barn record book into the office record book at the end of each week.

General Remarks.—Record under *General Remarks* in the barn record book any abnormal condition of the cows or change in their feeding or management, such as cows in heat, exposure, scoring in class room, loss of appetite, etc. Take body temperature of cows whenever any irregularity in their milk yields or general condition occurs.

Sampling of Feeding Stuffs—Corn Silage.—A two-quart jar full of silage is to be taken for a sample on Wednesday of every week during the experiment.

Corn in Silage.—Determine amount of grain in silage on Wednesday of every week, weighing out 50 pounds of silage in all cases. Take sample of the shelled corn so obtained.

Hay, Bran, Oats, Corn Meal and Oil Meal.—Take a sample of these feeds for each period, from sub-samples taken each Wednesday of the experiment.

The experiment progressed without any serious accident, all of the cows being continued on the experiment until its close. Three of the cows were sick for a short time during the experiment: Chloe had quite a serious attack of garget during the preliminary week of period I, but recovered during the end of the following week; Murphy was sick with indigestion for a few days durng the first and second week of period I, and Lizzie had a slight attack of garget during the last period. The cows on the experiment were used at times for demonstration purposes in the class room during the first and second periods, and thus subjected to more or less excitement; the work was, however, so arranged as to affect both lots in about the same manner. Great credit is due to J. Russell Danks, the herdsman, for the painstaking and careful attention given the cows during the experiment, to which much of the success of the experiment is attributable.

Temperature of stable.—The temperature of the stable was very uniform, and rather high, during period I. Toward the end of this period cold weather set in, which, aside from a few warm days during period II, first week, continued throughout this period. Period III was, on the whole, warm and sometimes close; a cold spell occurred during the second week of period III. The average temperature of the barn, calculated from tri-daily observations at 5 A. M., noon, and 6 P. M., are shown in the following table:

Average stable temperature.—Deg. Fahr.

	Preliminary week.	First week.	Second week.	Third week.	Average for period.
Period I	45.7	48.2	49 8	46 0	48.0
Period II	36.5	44.9	38.5	42.4	41.9
Period III	41.5	46.7	41.4	46.3	44.8

We notice that the average temperature for the last three weeks of period I was 48.0 degrees Fahr., and for the same weeks in period III, 44.8 degrees Fahr.; the mean of these figures is 46.4, which is 4.5 degrees higher than the temperature actually observed during period II. We shall consider later the relation between the low temperature during this period and the food consumption of the cows.

Data obtained on the experiment.—The following tables give the average results obtained with the cows for each period of the experiment, for live weight, amount of water drank per day, roughage eaten per day, and daily production of milk and fat. The data for period II (*increased grain-feeding* for Lot A) have in all cases been compared with the averages for periods I and III (*normal grain-feeding*), and the differences thus obtained are given for each cow; the average data for each lot of cows are given in the last four lines of the tables. The figures in the last column of the tables showing the per cent. of fat in the milk, were calculated by dividing the total production of fat times 100 by the total milk yield, and are not averages of the separate determinations of the percentages of fat obtained.

Summary tables for live weight, water drank, food eaten and production of milk and fat, per day—in pounds.

LOT A.	PERIOD.	Live weight.	Water drank.	ROUGHAGE.		PRODUCTION OF		Per cent. fat.
				Silage.	Hay.	Milk.	Fat.	
Duchess	I	1,227	67.1	45.2	3.9	28.8	1.10	3 82
	II	1,255	91.3	44.4	4.0	29.1	1.09	3.75
	III	1,252	60.5	48.0	4 0	24 0	.86	3.58
	*Difference.	+11	+27.5	−2.2	+.1	+2.7	+.11	+.05
Pauline	I	1,255	56 1	45.2	3.9	21.0	.81	3.86
	II	1,250	74.5	46.2	4.0	19.7	.77	3.91
	III	1,256	59 5	50.6	4 0	18.5	.71	3.84
	*Difference.	−5	+16.7	−1.7	0	−.1	+.01	+.06
Alma	I	882	77.6	41.0	3.9	28.8	.94	3.27
	II	907	86.8	42.3	4 0	28 1	.88	3.13
	III	916	84.6	44.0	4.0	28 2	.90	3.19
	*Difference.	+8	+5.7	−.2	0	−.4	−.04	−.10
Dora	I	1,046	57.5	41.1	4.0	25.4	1.10	4.33
	II	1,050	66.5	42.2	4 0	25.6	1.11	4.34
	III	1,076	52.1	46.0	4.0	21 5	.97	4 51
	*Difference.	−11	+11.7	−1.3	0	+2.1	+.07	−.08
Murphy	I	838	60.0	28.0	3.6	21.4	1 32	6.17
	II	839	60 7	36.0	4 0	22.4	1.25	5 58
	III	841	48.3	40.0	4.0	19.6	1.09	5.56
	*Difference.	0	+6.5	+2.0	+.2	+1.9	+.04	−.29
Bessie	I	819	57.3	41.0	3.9	27.7	1.30	4 69
	II	827	66.5	40.4	4.0	27 9	1.28	4 59
	III	822	56.6	42.0	4.0	25.5	1.17	4 59
	*Difference.	+6	+9 5	−1.1	0	+1.3	+.04	−.05
Princess	I	986	56.5	45.1	3.9	32.3	1.15	3.56
	II	993	56.3	46.1	4 0	30.8	1.11	3.61
	III	1,003	61.6	48.0	4 0	25.9	.98	3.78
	*Difference	−2	−2.8	−.4	0	+1.7	+.04	−.06
Nan	I	763	74.0	37.7	4.0	32.6	1.58	4.85
	II	728	76.8	35.5	3.8	28 0	1.41	5.04
	III	730	63.8	40.0	4.0	26.0	1.30	5.00
	*Difference.	−18	+7.9	−3 4	−.2	−1 3	−.03	+.11
General average.	I	**977**	**63.3**	**40.6**	**3.9**	**27.3**	**1.16**	**4.25**
	II	**981**	**72.4**	**41.6**	**4.0**	**26.4**	**1.11**	**4.21**
	III	**987**	**60.9**	**44.8**	**4.0**	**23.7**	**1.00**	**4.22**
	*Difference.	**−1**	**+10.3**	**−1.1**	**0**	**+.9**	**+.03**	**−.03**

* Difference is obtained by comparing data for period II with averages for periods I and III.

Summary tables for live weight, water drank, food eaten, and production of milk and fat, per day — continued.

LOT B.	PERIOD.	Live weight.	Water drank.	ROUGHAGE.		PRODUCTION OF		Per cent. fat.
				Silage.	Hay.	Milk.	Fat.	
Jane..............	I..........	1,035	74.1	45.0	3.9	29.2	1.05	3.60
	II..........	1,053	78.8	48.0	4.0	26.5	.95	3.59
	III..........	1,079	72.6	48.0	4.0	23.6	.88	3.73
	*Difference.	—4	+5.4	+1.5	0	+.1	—.02	—.08
Rose..............	I..........	1,135	54.5	50.0	3.9	20.8	1.04	5.00
	II..........	1,165	62.5	52.0	4.0	18.9	.99	5.24
	III..........	1,185	61.8	52.0	4.0	16.7	.86	5.15
	*Difference.	+5	+3.7	+1.0	0	+.1	+.04	+.16
Maud..............	I..........	1,065	67.0	45.0	4.0	27.1	1.07	3.95
	II..........	1,070	64.0	48.0	4.0	23.5	.97	4.13
	III..........	1,077	65.5	48.0	4.0	23.0	.9[illegible]	4.13
	*Difference.	—1	—2.3	+1.5	0	—1.6	—.04	+.09
Chloe..............	I..........	1,196	64.0	50.8	4.0	21.7	.80	3.69
	II..........	1,188	87.6	52.2	4.0	22.6	.78	3.45
	III..........	1,219	79.1	52.0	4.0	21.9	.73	3.33
	*Difference.	—19	+16.0	+.8	0	+.8	+.01	—.06
Dollie..............	I..........	1,034	61.1	41.0	4.0	25.9	1.22	5.10
	II..........	1,025	57.6	44.0	4.0	21.0	1.03	4.90
	III..........	1,040	58.5	44.0	4.0	19.1	.91	4.76
	*Difference.	—12	—2.2	+1.5	0	—.5	—.04	—.03
Lizzie..............	I..........	961	68.8	37.0	4.0	28.9	1.35	4.67
	II..........	979	65.3	38.1	4.0	26.0	1.27	4.88
	III..........	982	68.8	34.0	4.0	22.8	1.11	4.87
	*Difference.	+8	—3.5	+2.6	0	+.1	+.04	+.11
Goodrich..............	I..........	772	78.5	41.0	4.0	27.5	1.28	4.68
	II..........	812	84.0	44.0	3.9	27.4	1.29	4.71
	III..........	815	65.3	44.0	4.0	25.8	1.23	4.77
	*Difference.	+19	+12.1	+1.5	—.1	+.7	+.03	—.02
Campbell..............	I..........	1,086	68.1	41.0	3.9	31.2	1.19	3.81
	II..........	1,086	59.1	40.4	4.0	28.1	1.00	3.56
	III..........	1,093	54.0	40.0	4.0	24.9	.92	3.70
	*Difference.	—3	—2.0	—.1	0	+.1	—.06	—.20
General average.	I..........	**1,036**	**67.0**	**43.9**	**4.0**	**26.3**	**1.13**	**4.30**
	II..........	**1,047**	**69.9**	**45.8**	**4.0**	**24.3**	**1.03**	**4.24**
	III..........	**1,061**	**65.7**	**45.3**	**4.0**	**22.2**	**.95**	**4.28**
	*Difference.	**—1**	**+3.5**	**+1.2**	**0**	**0**	**—.01**	**—.05**

*Difference is obtained by comparing data for period II with averages for period I and III.

DISCUSSION OF RESULTS OBTAINED.

A. *Roughage eaten.*—It was stated in the introduction that an allowance of four pounds of hay were given per cow daily. As a rule the cows ate all the hay without waste, and in no case was more than a very small portion refused. The cows were fed as much silage twice a day as it was found from day to day that they would eat readily. It will be seen from the tables that Lot A on the average ate 1.1 lbs. less silage during the middle period as compared with the normal-grain periods, while Lot B, ate 1.2 lbs. more during the same time. All the cows in Lot A but one (Murphy) ate less during the second period than during the normal-grain periods; the reason why this cow behaved differently from the others in this respect is found in the fact that she was sick during the first period of the experiment and ate less silage in consequence than she did later on. The cows in Lot B ate more silage per head daily during the second period than during the other two periods, with the exception of one cow (Campbell) which ate more silage in the beginning of the experiment than at any time later. The only apparent reason for the greater consumption of silage by this lot during the middle period lies in the fact that the temperature of the stable at this time was considerably lower than before or after (see Stable temperatures).

B. *Live weight and water drank.*—On the whole both lots of cows gained somewhat in live weight during the experiment, the average weight of cows in Lot A increasing from 977 to 987 lbs., and those in Lot B from 1036 to 1061, i. e., an average increase of 10 and 25 pounds per head for Lot A and Lot B, respectively. We notice, however, that the increase in grain feed to Lot A during period II did not cause as large increase in live weight as was obtained in case of lot B during the same period, and there was exactly the same difference of 1 pound in the average live weight of the cows on the two lots between the weights for second period and the mean of the first and the last periods.

It will be observed from the tables given that three of the cows on Lot A increased in weight during the second period as com-

pared with the averages of the normal-grain periods, while four cows lost in weight, no difference being obtained in case of one cow. Of the cows in Lot B there were also three that increased in weight during the middle period as compared with periods I and III, while a decrease was obtained in case of five cows.

As a general rule the cows on the experiment drank more water during the second period than before or after. The average of Lot A for the period of heavy-grain feeding was 10.3 pounds above that of the normal-grain periods, and all the cows in this lot but one drank more water during this period than during periods I and III. In case of Lot B there was an increase in the amount of water drank in case of four cows, and a decrease for the same number. The average increase for all cows on this lot during the second period was 3. 5 pounds per head daily.

C. *Production of milk and fat.*—Discussing first the results obtained with the cows in Lot B, which received the same amount of grain throughout the experiment, we note that the average quantity of milk produced during period II was exactly the same as the mean of the quantities produced during periods I and III, while the production of fat was slightly less. The uniform decrease in the production of the cows during the different periods is remarkable, and adds great strength to the results obtained in the experiment. It shows that the feeding and the management of the cows were conducted under perfectly normal and favorable conditions, and that the system of feeding adopted at the beginning of the experiment was one that would insure a normal and uniformly high production of milk and fat. At the same time it must be granted that these strictly uniform results are in the line of a coincidence and it cannot be expected that they can often be duplicated. Only small differences were found in case of the different cows in the yields of milk and fat during period II as compared with the first and the last periods; six cows produced slightly more milk and two somewhat less, while in the production of fat there was a perceptible decrease or increase with four cows in both cases.

When the results obtained with Lot A are studied it will be seen that the heavy grain-feeding to this lot during the second period of the experiment resulted in an increased production of nine-tenths of a pound of milk and .03 of a pound of fat per head

daily, over and above the production during the normal-grain periods. Five cows gave more milk during the heavy-grain period, and three less, while six cows produced more fat and two less. The economy of the increase in the amount of grain fed to the cows during period II will be discussed presently under the head of economy of production.

The per cent. of fat in the milk produced by both lots of cows was slightly lower during the second period than the average for periods I and III, but in case of Lot A the decrease was not sufficiently pronounced to offset the gain in milk. The explanation of the decrease in the per cent. of fat during the second period is possibly to be sought in the lower temperature of the stable during this period, as compared with the temperature during periods I and III.

D. *Economy of production.*—We have seen in the preceding that the heavy grain-feeding did not materially affect the live weights of the cows during the experiment as compared with normal grain-feeding; the consumption of silage was decreased by about 2.3 pounds per head daily as a result of the increase in grain fed, and the daily production of milk was increased by about .9 of one pound per head, while there was a slight increase in the amount of fat produced. The following table gives the total quantities of feed eaten by the cows, and the total production of milk and fat for both lots of cows during the different periods of the experiment.

Total consumption and production — Per lot.

	Period.	Silage.	Hay.	Grain.	Milk.	Fat.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
LOT A. (Increased grain.)	I	6,813	219.1	1,344	4,581.8	193.40
	II	6,996	222.6	2,016	4,445.7	186.94
	III	7,530	224.0	1,344	3,972.7	167.95
	*Difference.	**−176**	**+1.0**	**+672**	**+168.4**	**+5.26**
LOT B. (Normal grain.)	I	7,372	222.3	1,344	4,416.3	189.16
	II	7,700	223.4	1,344	4,076.1	173.81
	III	7,602	224.0	1,344	3,735.1	159.38
	*Difference.	**+213**	**+.2**	**0**	**−.6**	**−.46**

*** Difference is obtained by comparing data for period II with average of I and III.**

We notice that Lot A (*increased grain*) ate 176 pounds less silage and one pound more hay during the second period than the average of the normal-grain periods, and produced 168.4 pounds more milk and 5.26 pounds more butter fat. Lot B, on the other hand, ate 213 pounds more silage during period II, .2 pound more hay, and lost .6 pound in milk, and .46 of a pound

	LOT A. PER I & III, NORMAL GRAIN. PER II, HEAVY GRAIN FEEDING.	LOT B. PER. I–III NORMAL GRAIN
PERIOD I.	6813 LBS. SILAGE. 219 " HAY. 1344 " GRAIN. 4581.8 LBS. MILIK. 195.40 " FAT.	7372 LBS. SILAGE. 222 " HAY. 1344 " GRAIN. 4416.3 LBS. MILK. 189.16 " FAT.
PERIOD II.	6996 LBS. SILAGE. 223 " HAY. 2016 " GRAIN. 4445.7 LBS. MILK. 186.94 " FAT.	7700 LBS. SILAGE. 223 " HAY. 1344 " GRAIN. 4076.1 LBS. MILK. 173.81 " FAT.
PERIOD III.	7530 LBS. SILAGE. 224 " HAY. 1344 " GRAIN. 3972.7 LBS. MILK. 167.95 " FAT.	7602 LBS. SILAGE. 224 " HAY. 1344 " GRAIN. 3735.1 LBS. MILK. 159.38 " FAT.

FIG. 1.—Diagram showing food consumption and production of milk and of fat by cows on the experiment.

of butter fat. In considering the question of the economy of the increased grain-feeding to lot A we may look at the results obtained with this lot as an experiment by itself, and also in conjunction with the results obtained with Lot B that received the normal-grain ration throughout the experiment.

In the former case we compare the food eaten and products obtained during the heavy-grain period with the averages of the two normal-grain periods. We then have:

By feeding 176 pounds less of silage, one pound more of hay and 672 pounds more of grain, an increase of 168.4 pounds of milk containing 5.26 pounds of butter fat was obtained.

Assuming the following average prices per ton for the feeds used: Silage $2.00, hay $6.00, and grain $15.00, the increased cost of the feed eaten during period II would be $4.86; estimating milk at $1.00 per 100 and butter fat at 20 cents per pound we have the gain in milk worth $1.68 and the gain in butter fat worth $1.05. In one case there was therefore a direct loss of $3.18, and in the other, a loss of $3.81, resulting from a fifty-per cent. increase in the grain ration of eight cows for a period of three weeks.

Secondly, the results obtained with Lot B are considered in calculating the economy of the heavy grain-feeding to Lot A during the second period. Since the two lots of cows were as uniform as possible at the beginning of the experiment we may be justified in assuming that they would have responded to a similar system of feeding in a like manner, and that whatever changes occurred in the food consumption and production of Lot B, would have occurred with Lot A in about the same manner if this lot had been fed a uniform grain ration throughout the experiment.

Lot A therefore ate about 389 pounds less silage and .8 pound more hay during the second period than would have been eaten if the lot had been on the same feed throughout the experiment, while the production of milk was about 169 pounds larger and that of fat 5.72 pounds larger, which may be credited to the additional 672 pounds of grain fed. At the same prices as before, this increased feed was worth $4.65, and the products obtained were worth $1.69, if the production of milk be used as a basis for calculation (milk at $1.00 a hundred), or $1.14 with fat at 20 cents a pound. In the one case a loss of $2.96 and in the other a loss of $3.51, resulting from the increase in the grain fed to eight cows during three weeks.

No matter therefore whether the cows in Lot A are considered by themselves or in comparison with those of Lot B, the feeding of the heavy grain-ration in both cases failed to increase the production to such an extent as to pay for the additional grain fed. If the increase in the production of butter fat by Lot A

be compared with the increase in food consumed we find that the former was obtained at a cost of 81 cents per pound of butter fat. This is, of course, a striking result, and would suggest that heavy grain-feeding of dairy cows will result in great loss to the feeder, but it must be observed that this method of calculation is in a measure misleading since the whole of the food and not the increase only, contributed to the increased production of butter fat during the heavy grain-feeding. A more correct method for ascertaining the economics of the production is to calculate the cost of the total rations fed in all cases and from this, the cost per pound of butter fat produced by the cows during the different periods of the experiment. The results of such calculations are presented in the following tables.

Cost of Food required for producing 1 lb. of butter fat.

	Lot A. Increased grain	Lot B. Normal grain.
Period I	9.0	9.6
Period II	12.2	10.6
Period III	10.8	11.6
Average of period I and III	9.9	10.6
Difference	2.3	0
In per cent	23 2	0

We notice that the cost of producing one pound of butter fat increased with the progress of the experiment in case of both lots, but while the increase in food cost was perfectly uniform for the three periods with Lot B, the cost with Lot A during the heavy-grain period increased from 9.0 to 12.2 cents, and again decreased in the following period to 10.8 cents. (See Fig. 2.) During the second period the food cost was therefore 2.3 cents higher per pound than the average of the normal-grain periods; that is, an increase of 23.2 per cent. in the cost of food required for making a pound of butter fat.

A study of the preceding small table will show that the increase during the experiment in the cost of the food required for producing a pound of butter fat was not the same in the case of the two lots, since it cost 1.8 cents more to produce a pound of

butter fat in case of Lot A during period III than during period I, while with Lot B the increase in cost was 2.0 cents. This difference may not be sufficiently large to signify much, but it may also suggest an after-effect during the last period resulting from the heavy grain-feeding to Lot A in period II.

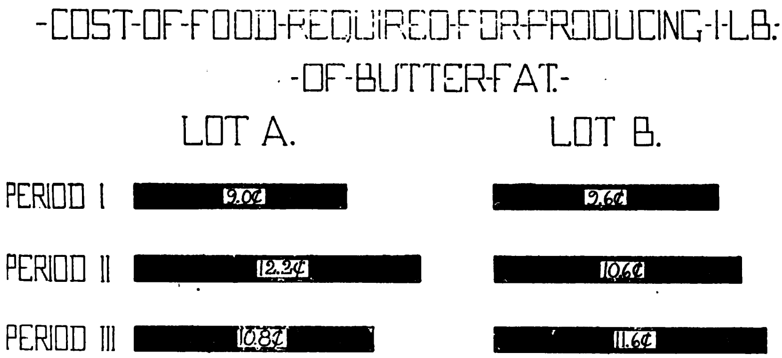


FIG. 2.—Diagram showing cost of food required to produce 1 pound of butter fat.

Production of milk and fat after close of the experiment.—In order to ascertain whether the effect of the heavy grain-feeding can be traced in the production of milk and fat after it had been discontinued, comparisons have been made between the production of the two lots in different weeks of the experiment and the average weekly production for two months after the experiment was ended on March 26th. The results thus obtained are seen in the following table:

Comparison of yields of milk and fat during different periods,— In pounds.

	Period II. Week 1.		Period II. Week 3.		Introd. to Period III.		Period III. Week 3.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.
Lot A	1,529.9	64.20	1,452.5	61.18	1,365.0	57.90	1,302.8	55.11
Difference	....	....	—77.4	—2.82	....	....	—62.2	—2.79
Lot B	1,412.5	59.33	1,320.2	56.22	1,300.6	56.64	1,207.0	51.19
Difference	....	....	—92.3	—3.71	....	....	—93.6	—5.45

	Period I. Week 1.		Period III. Week 3.		Period III. Week 3,		Mar. 26–Apr. 2.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.
*Lot A	1,561.1	68.26	1,302.8	55.11	1,302.8	55.11	1,245.7	55.71
Difference	....	....	—258.3	—12.85	....	....	—57.1	+.60
Lot B	1,469.8	64.69	1,207.0	51.19	1,207.0	51.19	1,212.6	53.01
Difference	....	....	—262.8	—13.50	....	....	+5.6	+1.82

	Mar. 26–Apr. 23		Apr. 23–May 21.		Introd. to Period III.		Apr. 23–May 21.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.
Lot A	1,245.7	55.71	1,287.4	54.31	1,365.0	57.90	1,287.4	54.31
Difference	....	....	+41.7	—1.40	....	....	—77.6	—3.59
Lot B*	1,095.0	46.83	1,133.1	47.80	1,174.2	49.93	1,133.1	47.80
Difference	....	....	+38.1	+.97	....	....	—41.1	—2.13

* Seven cows only.

A careful examination of the figures presented in this table will disclose the fact that the cows which received an increase in grain during period II went down less in milk and fat during every interval of the experiment for which comparisons have been made than did the cows receiving the same grain allowance throughout the experiment; during the heavy-grain period the total decrease was thus for Lot A, 77.4 pounds milk and 2.82 pounds fat; for Lot B, 92.3 pounds of milk and 3.71 pounds of fat; during the period following, the decrease for Lot A was 62.2 pounds of milk and 2.79 pounds of fat, and for Lot B 93.6 pounds milk and 5.45 pounds fat.

When we come to consider the production of the two lots of cows after the experiment was over, when all the cows received the same feed, the comparisons come out in favor of the lot that received the normal amount of grain during the whole experiment. This is contrary to what might be expected from the method of feeding adopted during the experiment, which would naturally tend to place Lot A in the better condition to maintain a good flow of milk for a period succeeding the experiment. The average number of days in milk for the two lots as well as the number of days before calving would also be likely to place Lot A at an advantage since the cows in this lot had been in milk an average of 72 days at the beginning of the experiment, and lot B an average of 108 days; and at this time the cows in Lot A were 306 days from the time they were due to calve, against 294 days for those of Lot B.

Two reasons suggest themselves as the possible causes why Lot B did better than Lot A after the experiment was over; one is that the cows in the former lot may have happened to be somewhat more persistent milkers than those in Lot A; the other, that the system of heavy grain-feeding perhaps had an unfavorable effect on the production of the cows in Lot A as compared with the other cows, by overtaxing the digestive capacity of the cows receiving the heavy grain-ration, thus placing them in a somewhat weakened condition for continued work. According to the experience of dairymen who have experimented with forcing the production of their cows, an increase in the amount of feed, especially of grain given, will often bring about an actual immediate decrease in production, and in such cases the production of the cow for a considerable time to come is also injuriously affected by the change. It is very likely that this explanation holds true for the cows of Lot A in this experiment, and that there was therefore not only no beneficial effect to be observed from the increase in grain, but this was an actual detriment to the cows when their production during the latter part of the lactation period was considered.

Production per unit of dry matter.—It will be remembered that the increase in the food supplied during the second period was entirely in the form of concentrated feeds, there being a consequent decrease in the amount of roughage eaten in this

period; both of these changes would tend, according to the modern teachings of the physiology of digestion, to make the rations richer in easily digestible food materials than those fed during the normal-grain period, and might be supposed to produce better results. In the following table the production of the cows per 100 pounds of dry matter consumed during the different periods has been calculated, with the results given.

Average production of milk and fat per 100 lbs. Dry matter.

Lot A.	Period.	Lbs. milk.	Lbs. fat.	Lot B.	Period.	Lbs. milk.	Lbs. fat.
Duchess	I and III.	98.9	3.7	Jane	I and III.	98.9	3.6
	II.	96.7	3.6		II.	98.9	3.5
Pauline	I and III.	90 4	3.5	Rose	I and III.	73 7	3.7
	II.	86 4	3.4		II.	74.4	3.9
Alma	I and III.	112 0	3.6	Maud	I and III.	100.0	4.0
	II.	95.6	3.0		II.	94 0	3.9
Dora	I and III.	97.9	4.3	Chloe	I and III.	82.3	2.9
	II	95.5	4.1		II.	85.9	3.0
Murphy	I and III.	98.1	5.8	Dollie	I and III.	97.7	4.9
	II	89 9	5.0		II.	95.0	4.7
Bessie	I and III.	114.0	5.3	Lizzie	I and III.	120.0	5.7
	II	107.0	4.9		II.	118.0	5.8
Princess	I and III.	121.0	4.5	Goodrich	I and III.	105.0	4.9
	II.	116.0	4.2		II.	108.0	5.1
Nan	I and III.	125 0	6.1	Campbell	I and III	126 0	4.8
	II.	108.0	5.4		II.	128.0	4.6
Average for Lot A:				*Average for Lot B:*			
Per. I and III		**109.0**	**4.6**	Per. I and III		**99.6**	**4.3**
Per. II		**99.3**	**4.2**	Per. II		**99.6**	**4.2**

So far from showing an increased production per unit of dry matter consumed during the heavy grain-feeding, there is in every case an actual decrease in the amounts of milk and fat produced, while practically the same production was obtained during all periods with the cows on Lot B receiving normal grain throughout the experiment. All cows on Lot A produced less milk and butter fat per 100 lbs. of dry matter during Period II, than the averages of Periods I and III; of the cows on Lot B, on the other hand, four produced somewhat more milk and three less, the same figure being obtained in case of one cow for these periods; four of the cows on this lot produced slightly more fat, and four slightly less.

The normal grain-allowance fed to Lot A was the amount considered sufficient for these cows to produce a maximum flow of milk without production of flesh; the results here shown can therefore offer no evidence against increasing grain rations that do not already meet this requirement.

NUTRIENTS IN RATIONS FED.

After having presented and discussed the main results of the experiment as regards the production of the cows, a few points remain to be given in connection with other data obtained on the experiment. We first call attention to the nutrients furnished the cows in the rations fed during the different periods. The chemical composition of the various feeds has been previously given and also the calculated digestible components of the feeds (page 40); from the data thus obtained the nutrients in the rations fed to the cows during the different periods have been calculated and are presented in the following table.

It should be remembered that the rations fed to the different cows were based on the results of close practical observation during several weeks prior to the experiment as to the effects of feeding varying amounts of grain and silage on the production of milk and the maintenance of the animals at a constant live weight, the object sought being to produce with a minimum supply of grain a maximum amount of milk, without any increase in live weight. The rations fed in all cases were therefore practical food rations and were decided upon with but little thought of their chemical composition or the amounts and kinds of nutrients furnished therein. As a matter of fact, the digestible components of the rations were not calculated until the chemical composition of the food stuffs used was ascertained more than a month after the close of the experiment.

Nutrients in rations fed — in pounds.

	PERIODS I AND III.					PERIOD II.				
	Dry matter.	Digestible protein.	Digestible carbohydrates.	Digestible fat.	Nutritive ratio.	Dry matter.	Digestible protein.	Digestible carbohydrates.	Digestible fat.	Nutritive ratio.
LOT A.					1:					1:
Duchess	26.67	2.10	14.90	1.03	8.2	30.07	2.70	16.72	1.20	7.2
Pauline	21.94	1.37	12.56	.83	10.5	22.77	1.59	13.31	.90	9.6
Alma	25.48	2.04	14.17	1.01	8.0	29.43	2.67	16.32	1.19	7.1
Dora	24.03	1.80	13.46	.95	8.6	26.79	2.29	14.98	1.07	7.6
Murphy	20.86	1.65	11.56	.86	8.2	24.90	2.20	13.80	1.12	7.3
Bessie	23.39	1.77	13.08	.93	8.5	26.24	2.26	14.64	1.06	7.5
Princess	24.11	1.72	13.60	.93	9.1	26.65	2.15	15.08	1.06	8.1
Nan	23.47	1.87	13.04	.94	8.1	25.87	2.37	14.28	1.07	7.0
Average Lot A	23.76	1.78	13.31	.94	8.6	26.61	2.28	14.87	1.07	7.6
LOT B.										
Jane	26.73	2.10	14.93	1.04	8.2	26.81	2.12	15.22	1.05	8.3
Rose	25.49	1.78	14.46	.97	9.3	25.39	1.80	14.65	.98	9.3
Maud	24.95	1.84	14.03	.97	8.8	25.03	1.86	14.32	.98	8.9
Chloe	26.48	1.91	14.97	1.01	9.0	26.31	1.92	15.12	1.02	9.0
Dollie	21.99	1.54	12.41	.87	9.3	22.11	1.56	12.69	.88	9.4
Lizzie	21.52	1.68	11.93	.88	8.3	22.02	1.72	12.43	.90	8.4
Goodrich	25.48	2.04	14.17	1.01	8.0	25.51	2.06	14.41	1.01	8.1
Campbell	22.22	1.63	12.46	.88	8.8	21.86	1.63	12.44	.88	8.8
Average Lot B	24.36	1.81	13.67	.95	8.7	24.36	1.83	13.90	.96	8.7

The data for the amounts of nutrients fed in the rations as well as the proportion of the various kinds of nutrients obtained were therefore as much of a surprise to the writers, as they are apt to be to the readers conversant with the accepted teachings of modern science as to the food requirements of dairy cows for the highest production of milk. The Wolff feeding standard which is best known in this country, and which has lately been modified by Lehmann and is now known as the Wolff-Lehmann standard, calls for a supply of digestible protein in the daily rations of 2.0 pounds or more to cows giving at least 16.6 pounds of milk per day, with a nutritive ratio of 1:6.0 or less.

Compared with this we find that the cows on Lot A received during the normal-grain periods on the average only 1.78 pounds digestible protein, the ration fed having an average nutritive ratio of 1:8.6 pounds; during the heavy-grain period the amount of digestible protein was increased to 2.28 pounds and the nutritive ratio narrowed to 1:7.6. The cows in Lot B received practically the same amounts of nutrients throughout the experiment, viz., on the average 1.8 pounds digestible protein, 13.8 pounds digestible carbohydrates, and .95 pound digestible fat, the nutritive ratio being 1:8.7.

It is not very many years since rations for dairy cows containing less than two and one-half pounds of digestible protein per day would have been condemned by authorities or writers on the subject of feeding dairy cows as entirely unscientific and inadequate for the needs of dairy cows in order to produce a large flow of milk. The investigations conducted by one of us (W.) in 1892 and 1893 as to the practice of feeding dairy cows in vogue among observing American dairymen were among the first in this country to call attention to the fact that the fixing of a definite minimum amount of digestible nutrients, and especially of protein, for the production of a good flow of milk is unwarranted, and that less protein than required by the Wolff feeding standard generally would prove more economical under our American, or at least western, conditions. The investigations referred to, which were published as bulletins No. 33 and 38 of this Station (now out of print) led to the publication of the so-called American practical feeding ration, which calls for a supply of the following amounts of the different nutrients in the daily ration of a dairy cow in full flow of milk, viz., digestible protein 2.15 pounds, digestible carbohydrates 13.27 pounds, digestible fat .74 pound; nutritive ratio 1:6.9.

It will be observed that the amounts of digestible protein supplied in the rations fed to the different cows on the experiment under discussion in every case fell below that required by the American feeding ration during the normal-grain periods, and during the heavy-grain feeding one cow received less protein, while the average was .13 pound more. The increased

amount of protein and other digestible components and the narrowing of the nutritive ratio during the heavy grain-feeding failed to bring about any increased production of milk or fat as compared with the periods when the less amounts were fed, and so far as the results obtained in this experiment are concerned, no advantage was derived from the larger supply of protein or the narrowing of the nutritive ratio of the feed during the heavy grain-feeding. The nutritive ratios of the rations fed to the different cows was in every case much wider than that called for by the Wolff-Lehmann standard, or even the American feeding ration, and in view of this fact the results obtained as to the effect of the heavy grain-feeding are all the more striking.

SUMMARY.

The experiment reported in the preceding is the second one conducted at this Station in the study of the economy of heavy grain-feeding of dairy cows. The results obtained corroborate in general those of last year's experiment, as given in the 16th annual report of this Station. The main results of the experiment here described may be briefly summarized as follows:

1. Eight cows whose grain allowance was increased by 50 per cent. during the second period of the experiment, viz., from eight to twelve pounds on the average per head and per day, or a total increase of 672 pounds of grain during the last three weeks of the period, ate 126 pounds less corn silage and one pound more of hay during this period than the average of three weeks during the preceding and the following periods. The change in the method of feeding resulted in an increased production of 168.4 pounds milk and 5.26 pounds butter fat. At ordinary market prices of feeds and products the increase in production of the cows was obtained at a loss of $3.81, or at the rate of 81 cents per pound of butter fat (p. 51).

2. Comparing the production of these cows with that of the eight other cows included on the experiment which were fed the same amounts of grain the whole time, we find that the increase in production was brought about at a total loss of $3.51 for the eight cows during the twenty-one days (p. 51).

3. The cost of the food required for producing one pound of

butter fat was increased during the heavy grain-feeding by 23.2 per cent. over the cost during the normal-grain periods (p. 52).

4. The heavy grain-feeding did not tend to maintain the milk or fat production of the cows better during the two months following the experiment than did the normal grain-feeding. On the contrary, the after-results were decidedly in favor of the normal grain-feeding; this result suggests that the digestive systems of the cows was overtaxed by the increased grain-feeding during the middle period of the experiment (p. 54).

5. The production of milk and fat per 100 pounds of dry matter consumed decreased in case of all cows during the heavy grain-feeding, and on the average from 109.0 to 99.3 pounds milk and from 4.6 to 4.2 pounds fat per 100 pounds dry matter consumed; the production of the control lot remained practically constant at 99.6 and 4.3 pounds of milk and butter fat, respectively, per 100 pounds of dry matter consumed in the food (p. 56).

6. The results of the experiments in this line conducted by us during the last two years lead to the general conclusion that it does not pay to feed dairy cows more than a medium amount of grain feed which may be placed at about 8 pounds per head daily, except in case of cows of marked dairy tendencies that respond to heavy grain-feeding by an increased production of milk and fat rather than by a gain in live weight. It is planned to continue this investigation during next year and later, until the general subject of the economics of feeding dairy cows has been studied in its varying phases.

OFFICIAL TESTS OF DAIRY COWS, 1899-1900.

F. W. WOLL.

For a number of years past the Station has frequently been called upon by various breeders' associations to conduct official tests of pure-bred dairy cows.* These tests, which are commonly known as Official Tests of Dairy Cows, are continued for a period varying from two to ten days; in a large majority of cases they cover a period of seven days. During the past year they have been conducted on a larger scale than in any previous year, and it is very likely that this system of testing will be adopted more and more by breeders of dairy stock in the future, since purchases on basis of the actual performance of a cow or her ancestors are now becoming general, while up to within the last few years such purchases were but rarely made. Under these conditions it is more important than ever that the tests shall be conducted by some disinterested party under such conditions and with such safeguards thrown around them as to admit of no doubt concerning the correctness of the results obtained. As the rules under which official tests are conducted by this Station have not been previously formulated in detail, it was decided to do so last year for the guidance of breeders and our Station representatives, and in conference with the Station officers more directly interested in this subject, viz., Director Henry, Dr. Babcock, Prof. Carlyle and the writer, the following General Rules Regarding the Conduct of Official Tests of Dairy Cows and Directions for Station Representatives in Conducting Official Tests of Dairy Cows were agreed upon; these rules went into effect January 1st, 1900, and all but six tests made during the past year have been conducted under these rules.

* For accounts of Official Tests of Dairy Cows conducted by this Station in the past, see Reports XI, p. 205; XIII, p. 164; XV, p. 30, and XVI, p. 140.

I. GENERAL RULES REGARDING THE CONDUCT OF OFFICIAL TESTS OF DAIRY COWS, UNIVERSITY OF WISCONSIN, AGRICULTURAL EXPERIMENT STATION.

The Agricultural Experiment Station of the University of Wisconsin, working in conjunction with the various breeders' associations, will conduct official tests of registered dairy cows under the following conditions:

1. All tests will be conducted by the representative of the Station. Not less than two weeks' notice of the desired test shall be given by the owner on a blank which will be furnished on application by the Station.

2. It is understood and agreed that the person for whom the test is made will pay all expenses in connection with the test. The compensation for the Station representative conducting the tests, unless otherwise arranged, shall be $2.00 per day for each day of the test. The person for whom the test is made will also pay the necessary traveling expenses and provide for the accommodation of the Station representative while conducting the test.

The Station representative will present a bill of expenses to the owner of the cow or cows tested, on completing the test, and will send a duplicate of the same with his report to the Station. This bill must be paid to the Station by the owner before the report of the test is transmitted to the Association. The Station will pay the funds so received to its representative.

3. The Station will furnish its representative with the necessary apparatus to conduct the test. This will consist of

(1) A spring balance for weighing the milk.

(2) A Babcock tester and accompanying complete apparatus for testing the milk.

(3) A 25 cc. pipette for taking composite samples.

(4) A clinical thermometer.

(5) Blanks, affidavits, etc., for making the returns.

4. The Station representative shall fill out all blanks furnished by the Station as required, and shall make oath before a notary public to such statements as are required by the Station in conjunction with the authorities of the various associations.

5. If required, the Station representative shall make a report on the kinds and quantities of feed given during the test, and on the description and measurements of the cow or cows tested.

He shall take the body temperature of all cows tested at least once a day during the test, preferably between 2 and 3 P. M.

The Station reserves the right to make public in its reports and bulletins, or by other means, any and all findings secured while conducting official tests.

II. DIRECTIONS FOR STATION REPRESENTATIVE IN CONDUCTING OFFICIAL TESTS OF DAIRY COWS.

1. The Station representative shall be present at the last regular milking preceding the beginning of the test and shall satisfy himself that the cow is milked dry at that time. He shall note the hour at which this milking is made, and the final milking of the test must be made seven days later at the same hour.

2. He must be present at each and every milking during the test and satisfy himself that at the close of each milking the pail contains nothing but the milk drawn from the cow under test.

3. Under no circumstances can more than one cow undergoing test be milked at the same time. The Station representative must in every case be in position to observe the milker during the whole milking.

4. Immediately after the milk is drawn at each milking he will take charge of the pail and contents, will weigh the same on scales provided by the Experiment Station, and enter the exact weight of milk at once on his records. He will then take a correct sample of the milk for his own tests and for the composite sample to be sent to the Station, in accordance with the following directions.

Concerning Sampling and Testing of Milk.

5. As soon as the milk has been weighed it is thoroughly mixed by pouring it from one pail to another, or by means of a dipper, and a pint fruit-jar is immediately filled about two-thirds full of milk for the test sample. The Station representative takes charge of and is personally responsible for this sample and shall keep it under lock and key until tested. The test is proceeded with as soon as convenient after the milk has cooled to ordinary room temperature.

6. Fat determinations are always made in duplicate, and the average of the two determinations recorded on the record sheet. The sample taken of any one milking is not thrown away until a perfectly satisfactory test of the milking has been obtained. The Station representative will enter at once the results obtained on the proper blanks, in ink or indelible pencil, on completion of each test.

7. If any of the milk or the test-sample from a milking is accidentally lost, the missing weight or the test credited to this milking is to be obtained by taking the average of all corresponding milkings during the whole test; if, e. g., the evening milking is lost or the test-sample therefrom, the average of the weights or tests of all evening milkings during the seven-day test is taken as the yield or test for the one lost. It must be stated on the report that data so obtained are estimated and not actual.

8. *Composite-test sample.*—At the time the test of the milk is made, a sample comprising as many cubic centimeters of milk as the number of pounds in the milking, is placed in a pint fruit-jar containing a small quantity of preservative, for the composite-test sample to be sent to the Station when the test is completed. A 25 cc. glass pipette for taking this sample is furnished in each outfit.

Each and every milking must contribute to the composite-test sample, in the proportion to the amount of milk yielded each time, which will be accomplished by following the method of procedure given.

The Station representative will be responsible for the proper care of the composite sample, and will send it by express, charges prepaid, immediately on the completion of the test to Prof. F. W. Woll, Agricultural Experiment Station, Madison, Wis.

9. The Station representative is not at liberty to decide as to which stipulations contained herein are essential and which are not, but is required to observe these directions in all details. He shall report any irregularity or unusual occurrence in connection with the test which he may observe, and shall in general take all possible means to conduct a fair and equitable test of the cows placed under his supervision.

Thirty-five different tests were made in all during the year, varying in length from two to fourteen days; the tests were conducted for sixteen different breeders, 132 different cows being tested in all. The expenses of the individual tests ranged from $10.00 to $49.58, the latter figure being for a fourteen-day test; the average cost of a seven- or eight-day test to the breeders came to $19.44.

As in previous years, the main work in this line has been done in conjunction with the Holstein-Friesian Association of America, but members of other breeders' assocations have been invited through the dairy press or through personal correspondence to avail themselves of the services of the Station in conducting these tests. The Guernsey, Shorthorn, and Red Polled, are, however, the only breeds that are represented in these tests during the past year, besides the Holstein-Friesian.

It is not the intention to discuss at this time the results of the tests made during the past year, but rather to wait until the work has been continued for several years, when it is believed much valuable material will have been accumulated that may throw light on many questions relating to the milk- and butter-fat production of dairy cows, the physiology of milk production,

influence of age, heredity, etc. It is only on account of the information which may be gathered on questions of this character that we feel justified in giving up so much of the time and energy of the Station force to these tests, and it is one of the fundamental conditions for conducting the tests that we shall be free to publish the results and use the material thus obtained for enlarging our knowledge of problems in dairy production in all ways that may suggest themselves to us.

The tests made for the different breeders' associations will be described under separate headings, and we begin with the official tests of Holstein-Friesian cows.

A. OFFICIAL TESTS OF HOLSTEIN-FRIESIAN COWS.

One hundred and ten different cows were tested during the year; two separate tests were made of fifteen cows, and three tests of one cow, making one hundred and twenty-sevn single tests of Holstein-Friesian cows that were conducted last year. Of these cows, forty-two were five years old and over; nine were four to five years old; twenty-seven were three to four years old, and thirty-one were under three years. In the following tables the cows undergoing official tests have been arranged in four classes, according to their respective ages, and the average data for the cows in each class have been calculated.

The names of the owners of the different cows tested will be seen below, the number given in each case referring to the number of the cows in the subjoined tables:

G. W. Campbell, Ripley, Wis., No. 96.

W. S. Carpenter, Menominee, Mich., Nos. 16, 17, 42, 47, 50, 51, 63, 64, 78, and 108.

A. J. Daugherity, Streator, Ill., Nos. 9, 10, 11, and 58.

W. R. Gates, Ripley, Wis., No. 71.

Gillett & Son, Rosendale, Wis., Nos. 3, 4, 26, 27, 35, 44, 55, 56, 68, 82 94, and 99.

W. H. Jones, Hustisford, Wis., Nos. 1, 18, 30, 39, 40, 52, 69, 70, 79, 89, 93, 95, and 105.

S. B. Jones & Son, Hustisford, Wis., Nos. 7, 8, 31, 32, 33, 34, 43, 53, 57, 61, 62, 72, 81, 83, 84, 85, 97, and 98.

A. N. McGeoch, Lake Mills, Wis., Nos. 13, 14, 15, 23, 24, 25, 46, 59, 60, 65, 66, 67, 73, 87, 88, 89, 90, 91, 92, 92a, and 107.

E. C. Petrie, Bowers, Wis., Nos. 41, 77, and 106.

E. E. Randall, Hustisford, Wis., Nos. 2, 5, 6, 19, 20, 21, 22, 45, 54, 74, 75, 100, 101, and 102.

J. Rust, North Greenfield, Wis., Nos. 36, 37, 38, 49, 76, 103, and 104.

C. A. Schroeder, West Bend, Wis., Nos. 12, 28, 29, 48, and 86.

The majority of the tests were conducted by Charles A. Nicolaus, of Troy Center, Wis., as our Station representative, viz., all except of the cows given in the following, tests of which were conducted by the parties mentioned:

J. D. Clarke, Milton, Wis., tested cows Nos. 18, 19 (first test), 20, 21, 22, 30, 61, 62 (first test), 69, 70 (first test), 93, and 95 (first test).

P. A. Dukleth, Big Bend, Wis., tested cows Nos. 23, 24 (first test), 25 (first test), 65, 66, and 67 (first test).

Wm. W. Hamlyn, West Bend, Wis., tested cows Nos. 12, 28, 29, 48, and 86.

George C. Hill, Rosendale, Wis., tested cows Nos. 3, 4, 44, 55, 56, and 82.

Abe Sauers, Bluff Siding, Wis., tested cows Nos. 26, 27, 35, 68, 94, and 99.

One re-test was made by the writer during the year, on request of Mr. S. Hoxie, Superintendent of Advanced Registry, Yorkville, N. Y., viz., of cow No. 55, with results that confirmed those obtained in the seven-day test given below.

The results of the official tests of Holstein-Friesian cows conducted during the past year are shown in the following tables, the total yields of milk and butter fat for seven consecutive days being given, with the average per cent. of fat in the milk for this period, the variation of fat content in single milkings, variation of daily yield of fat, and data showing the body temperature of the cows during the tests.

Records of official tests of Holstein-Friesian cows, 1899-1900.

Cow No.	NAME.	Registry No.	Test began.	Age.	Days in milk.	Milk.	Fat.	Average per ct. fat.	Fat, variation in: Min.	Fat, variation in: Max.	Fat per day: Min.	Fat per day: Max.	Body temp. of cow: Aver.	Body temp. of cow: Range.
				Y. M. D.		Lbs.	Lbs.		Per ct.	Per ct.	Lbs.	Lbs.	° F.	° F.
	Class I.—Cows five years old or over:													
1	Spring Brook Queen	1 700	Aug. 22	6— 2—26	11	368.1	12.787	3.47	2.6	4.4	1.63	2.01	....	....
2	Ollie Watson	28,140	Sept. 21	8— 6— 5	10	270.1	8.263	3.06	2.5	3.85	1.12	1.28	....	....
			Dec. 13	8— 8—26	92	285.9	8.974	3.14	2.3	4.4	1.15	1.37	....	....
3	Colantha 4th	35,028	Dec. 7	6— 9—17	39	513.6	19.593	3.79	2.8	5.1	2.64	3.14	....	....
3	Johanna De Kol	36,478	Dec. 7	5— 9— 3	28	410 1	15.498	3.78	2.5	4.8	2.02	2.43	....	....
5	Alcarthia 2d Clothilde	44,431	Dec. 13	5 — 7—18	33	362.7	13.189	3.64	2 5	4.9	1.65	2.06	....	....
6	Wisconsin Bride	45,145	Dec. 13	5— 4—11	29	331.7	12.011	3.62	2.8	4.9	1.40	1.88	....	....
7	Glen Rose 3d	44,121	Dec. 20	5— 3—22	34	352.4	10.771	3.06	2.6	3.6	1.42	1.73	....	....
8	Jessie Fobes 2d	28,772	Dec. 20	8— 9—10	44	361.2	9.956	2.76	2.5	3.2	1.34	1.56	....	....
9	Pietertje Lass	29,726	Jan. 3	8— 8—14	80	362.8	12.176	3.36	3.0	4.5	1.57	2.01	101.9	101.4-2.7
10	May Rector	11,457	Jan. 3	5— 7— 8	16	471.5	14.611	3.10	2.4	4.1	1.97	2.22	103.3	102.7—3.7
11	Jessie Rector	....	Jan. 3	6— 4—18	71	304.4	9.703	3.19	2.8	3.8	1.32	1.44	102.1	101.8—2.6
12	Netta Netherl. Van Beers	31,401	Jan. 4	8— 1—15	37	398.5	14.051	3.53	2.8	4.8	1.79	2.28	101.1	100.8—1.4
12	Aaltje Solo 5th Trit	34,137	Jan. 12	7— 4—10	31	409.6	13.143	3.21	2.5	4.25	1.75	2.01	101.1	99.8—2.4
14	Bakker Bell 3d	36,466	Jan. 12	6— 2— 2	89	283.7	9.018	3.18	2.4	4.2	1.21	1.27	101.9	101.4—2.5
15	Melisse Clothilde	[5] 31,371	Jan. 19	6— 4—29	3	421.6	15.912	3.77	2.2	5.3	1 40	2.92	101.8	100.9—2.4
			Jan. 26	6— 5— 6	10	452.9	14.707	3.25	1.8	4.8	1.90	2.33	101.8	101.4—2.2
16	Bell Pentour	20,361	Feb. 8	10— 1— 3	31	360.5	11.490	3.19	2.3	4.4	1.58	1.72	102.1	101.5—4.6
			Feb. 15	10— 1—10	33	396.4	12.675	3.20	2.3	4.0	1.70	1.92	[2]101.2	101.0—1.4
17	Kitty Clyde 2d Coral	[3] 33,958	Feb. 8	7— 4— 6	59	137.7	3.631	2.61	2.2	3.4	1.17	1.25	101.7	101.5—1.8
18	Lottie Lass 2d	41,120	Feb. 13	6—10—11	15	328.4	10.620	3.23	2.8	3.8	1.46	1.57	....	....
			Apr. 3	7— 0— 1	61	278.8	8.367	3.00	2.85	3.2	1.17	1.22	101.2	100.4—2.2
19	Rose Aaggie Liddisdale	11,413	Mar. 6	5— 9—24	11	423.0	13.680	3.23	2.8	4.7	1.72	2.18	....	....
			May 10	5—11—28	76	413.0	13.667	3.31	2.4	4.4	1.84	2.10	101.0	100 4—1.6
20	Alcarthia 2d Rose	44,430	May 6	6—11— 4	45	305.1	10.500	3.44	2.6	4.3	1.38	1.60	....	....
21	Olive De Cola	28,417	May 6	5— 5—21	11	351.7	11.784	3.35	2.93	3.75	1.59	1.71	....	....
22	Meg Van Beers	45,147	May 6	5— 2—26	2	270.7	10.175	3.76	3.4	4.75	1.24	1.58	....	....
23	Duchess of Ormsby 2d	35,439	Jan. 26	6—10—22	7	409 8	17.048	4.16	2.85	5.4	2.07	2 67	102.7	102 3-3 6
			Mar. 13	7— 0—13	52	361.2	13.318	3 68	2.3	6.2	1.61	2.25	103.0	102.0-4.0
24	Piebe Laura	27,248	[4]Mar. 20	8—10— 2	4	372.7	17.084	4.58	3.6	5.7	2.24	2.58	101.9	101.5-2.2
			Mar. 27	8—10— 9	11	387.2	14.956	3.86	2.4	5.2	1.86	2.46	101.7	101.0-2.2

[1] Western Herd Book. [2] Two observations. [3] Three-day test. [4] Best 7 days: 374.8 lbs. milk, 17.239 fat, 4.61 per ct. fat.
[5] Best 7 days, Jan. 21-27, 437.4 lbs. milk, 16.771 lbs. fat; average per ct. fat, 3.83.

25	Rixa Silva 3d Pietertje	37,258	Jan. 26	5—10—29	9	345.8	12.065	3.49	2.6	4.4	1.55	1.92	101.1	100.3-1.6
			Mar. 13[1]	6— 0—14	59	334.9	11.577	3.46	2.1	4.85	1.33	2.02	101.4	100.5-4.0
			May 1	6— 2— 4	105	339.9	11.923	3.51	2.2	5.3	1.57	1.94	101.1	100.6-1.7
26	Johanna Aaggie	36,477	Mar. 18	6— 4— 0	17	403.1	16.870	4.19	3.4	5.65	2.19	2.74	101.9	101.2-2.2
			Mar. 25	6— 4— 7	24	398.4	15.857	3.93	3.4	4.5	2.13	2.47	....	....
27	Nina Melchior	24,500	Mar. 18	10— 0— 0	4	319.7	12.529	3.92	3.0	4.95	1.51	2.00	101.6	101.1-2.9
28	Linda Wit	20,072	Mar. 27	10— 1—20	7	409.9	15.116	3.69	3.0	4.2	2.01	2.39	101.4	101.0-1.6
29	Netherl. Lucy Wit	48,996	Mar. 27	5— 3— 9	23	391.1	14.210	3.63	3.0	4.4	1.88	2.16	101.5	101.4-1.6
30	Piebe Queen	29,065	Apr. 3	8— 1— 9	15	373.8	12.171	3.25	2.55	4.07	1.70	1.90	101.3	101.1-1.4
31	Lady Oak 2d	39,917	Apr. 15	5— 0—25	3	350.2	14.643	4.18	3.6	4.7	1.91	2.27	101.8	101.4-2.2
32	Lady Longfield	32,290	Apr. 15	7—11— 5	45	366.9	12.878	3.51	2.9	4.5	1.66	2.00	101.7	101.0-2.0
33	Susan Strong	39,914	Apr. 15	5— 0— 4	5	290.1	9.001	3.10	2.7	3.6	1.19	1.36	102.1	101.7-2.4
34	Winaifred Pride 2d	41,118	Apr. 15	6—11—16	7	409.3	11.401	2.79	2.4	3.2	1.51	1.64	102.3	101.8-2.5
35	Duchess Clothilde	24,893	May 17	9— 2— 0	11	528.4	18.422	3.49	2.7	4.6	2.46	2.94	....	....
36	Piebe 5th[2]	35,246	May 20	6— 7—15	24	447.9	15.306	3.42	2.6	3.9	2.03	2.28	101.9	101.0-3.1
37	Aaltje Salo Princess 3d[3]	38,802	May 20	5— 3—20	47	378.9	14.037	3.72	2.8	4.6	1.76	2.39	101.7	100.2-3.4
38	Akkrummer 7th[4]	36,462	May 20	6— 7— 3	123	145.3	4.830	3.31	3.0	3.6	1.58	1.66	101.4	101.0-1.6
39	Big Jane	43,602	May 29	6— 3— 1	32	404.7	11.013	2.72	2.1	3.7	1.37	1.69	101.1	100.6-1.8
40	Aaltje Salo Queen 2d	40,857	May 29	7— 0— 8	111	325.0	9.746	3.00	2.4	3.4	1.32	1.45	100.8	100.1-1.2
41	Hertha Boon Mercedes	39,320	June 8	6— 0—11	13	333.0	12.017	3.61	2.9	4.5	1.58	1.79	100.9	100.2-1.2
42	Lady Longfield 3d	39,945	July 3	5— 3—17	56	423.6	13.770	3.25	2.6	4.2	1.91	2.08	....	....
	Average for 50 7-day tests	....	....	....	33	371.9	12.89	3.47	1.8	5.7	1.12	3.14	101.6	99.8-4.6
	Class II.— Cows four years old and under five.													
43	Pauline Whitney	39,946	Aug. 30	4— 5—25	3	324.7	13.246	4.08	2.7	5.4	1.75	2.19	....	....
			Dec. 20	4— 9—15	115	252.5	9.452	3.74	3.1	4.4	1.24	1.41	....	....
44	Johanna Clothilde	40,384	Dec. 7	4— 7— 4	77	348.9	14.059	4.03	2.8	5.7	1.95	2.01	....	....
45	Greeting Helpless	44,437	Dec. 13	4— 0—12	41	238.2	9.824	4.13	3.2	5.0	1.30	1.47	....	....
46	Flora Bell Pietertje	39,322	Jan. 12	4— 2— 4	150	251.3	7.832	3.12	2.6	4.2	1.07	1.18	100.8	100.0-1.4
47	Ginger	40,757	Feb. 8	4— 3—22	21	346.5	9.431	2.72	2.3	3.5	1.31	1.38	101.5	100.8-1.8
48	Lucy Wit 2d	44,231	Mar. 27	4— 3—18	16	351.4	13.579	3.90	3.2	5.0	1.73	2.18	101.8	101.2-3.6
49	Akkrummer 3d Piet[5]	40,861	May 20	4— 2— 5	53	124.0	4.040	3.26	2.8	3.6	1.29	1.38	101.0	100.1-1.7
50	Sylva Thorns	42,079	July 3	4— 1—23	55	346.3	12.675	3.66	1.8	5.4	1.63	1.92	....	....
51	Rose Zoldusky Pauline	45,755	July 3	4— 3— 7	22	335.6	11.183	3.33	2.4	4.4	1.53	1.69	....	....
	Average for 8 7 day tests	....	....		56	310.6	11.25	3.62	1.8	5.7	1.07	2.19	101.3	100.0-3.6
	Class III.— Cows three years old and under four.													
52	Heilo 4th Pet	43,611	Aug. 22	3—11— 2	7	331.1	11.011	3.33	2.9	3.9	1.47	1.69	....	....
53	Lost Wonder	41,918	Aug. 30	3—11—20	16	312.0	9.565	3.07	2.6	3.6	1.31	1.47	....	....
54	Alcartia Nan Beers	49,317	Sep. 21	3— 4—15	19	178.5	5.962	3.34	2.4	4.8	0.75	1.11	....	....
55	Johanna De Pauline	42,169	Dec 7	3— 2—25	9	323.7	14.971	4.63	2.7	7.0	1.97	2.28	....	....

[1] Twelve-day test: 575.9 lbs milk, 19.124 lbs. fat, 3.32 per ct. fat
[2] Ten-day test: 617.4 lbs. milk, 20.784 lbs. fat, 3.36 per ct. fat.
[3] Ten-day test: 534.8 lbs. milk, 18.311 lbs. fat, 3.42 per ct. fat.
[4] Three-day test.
[5] Three-day test.

Record of official tests of Holstein-Friesian cows, 1899-1900.—Continued.

Cow No.	Name.	Registry No.	Test began.	Age.	Days in milk.	Milk.	Fat.	Average per ct. fat.	Fat, Variation in: Min.	Fat, Variation in: Max.	Fat per Day: Min.	Fat per Day: Max.	Body Temp. of Cow: Aver.	Body Temp. of Cow: Range.
	Class III.—Cows three years old and under four—cont.			Y. M. D.		Lbs.	Lbs.		Per ct	Per ct.	Lbs.	Lbs.	° F	° F
56	Johanna Rue 3d	42,167	Dec. 7	3—8—12	37	411.3	15.204	3.70	2.5	5.2	1.98	2.27	....	....
57	Lady Oak 3d	41,725	Dec. 20	3—10—11	29	404.9	12.108	2.99	2.3	3.5	1.62	1.80	....	....
58	Pietertje Lass 2d	50,657	Jan. 3	3—0—28	21	282.8	10.246	3.62	3.4	4.0	1.42	1.49	102.7	102.2-3.7
59	Bakker Bell Pietertje	41,995	Jan. 12	3—9—28	109	302.6	11.401	3.77	3.1	4.9	1.44	1.83	101.6	101.0-2.1
60	Kakenstein	43,974	Jan 12	3—1—8	88	172.1	5.684	3.30	3.0	4.0	.75	.89	101.5	100.7-1.8
61	Jessie Fob. 2d Tritomia	44,130	Feb. 20	3—1—24	21	378.5	12.703	3.36	2.45	4.15	1.73	1.87		
62	Grace Fayne 2d	44,124	Feb. 20	3—1—19	8	338.1	10.314	3.05	2.5	3.8	1.34	1.62	....	....
			Apr. 15	3—3—13	58	343.8	11.410	3.32	2.7	4.0	1.46	1.44	102.3	101.8-2.8
63	Fanny Douglas 4th	41,943	Apr. 8	3—10—7	19	321.6	10.130	3.10	2.7	4.0	1.38	1.50	101.4	100.4-2.3
64	Ollie Watson 3d	41,944	Apr. 8	3—11—13	5	317.5	9.219	2.90	2.35	4.0	1.24	1.44	101.7[1]	101.6-1.7
65	Aaltje Salo Tritomia	43,979	Mar. 13	3—7—4	81	343.4	7.527	3.13	2.0	4.3	.93	1.16	100.6	99.4—1.5
66	Husky Josephine Aa tje[2]	43,983	Mar. 13	3—5—6	9	315.1	10.515	3.34	2.3	4.1	1.41	1.63	101.7	101.0—2.1
67	Wit Duchess [3]	43,953	Mar. 13	3—5—23	14	351.9	9.461	2.69	1.5	4.35	1.07	1.59	101.4	100.5—2.5
			May 1	3—8—27	64	310.7	9.618	3.10	1.8	4.0	1.21	1.60	101.7	101.4—2.0
68	Rijanetta Clothilde	42,949	May 18	3—6—0	6	302.0	13.612	4.51	2.5	7.0	1.62	2.26	102.1	101.4—2.4
69	Lill Black's Piet. De Kol	45,976	Apr. 3	3—6—3	5	244.9	8.420	3.44	2.8	4.03	1.12	1.31	101.3	101.9—2.4
70	Jess De Kol	45,977	Apr. 3	3—5—7	38	266.6	9.574	3.59	3.15	4.1	1.29	1.41	101.3	101.1—1.4
			May 29	3—8—11	94	281.9	9.542	3.38	3.0	3.6	1.30	1.42	101.3	101.0—1.6
71	Melisse Clothilde 2d	42,842	May 4	3—3—19	8	397.6	11.731	2.95	1.8	4.2	1.47	1.88	102.5	102.0—3.0
72	Lady Longfield 4th	44,125	May 15	3—2—16	22	391.5	13.677	3.49	2.6	4.5	1.73	2.14	101.6	100.3—2.4
73	Jessie Parthenea	49,597	May 1	3—0—1	25	259.6	8.957	3.45	2.9	4.6	1.20	1.35	101.5	101.4—1.8
74	Jessie Griefe	44,153	May 10	3—1—29	20	295.3	9.951	3.37	2.8	4.3	1.27	1.51	101.0	101.6—4.6
75	Minerva Netherland	44,435	May 10	3—3—29	42	305.6	10.563	3.46	2.5	4.8	1.37	1.62	[5]105.2	....
76	Schoone Queen [4]	43,384	May 20	3—8—22	561	55.4	1.937	3.50	3.3	3.7	.94	.99	....	....
77	Shadeland Mechthilde	50,187	June 8	3—3—8	56	426.6	13.788	3.23	2.4	4.2	1.86	2.16	101.2	100.2—1.8
78	Paula Goldie	43,516	July 3	3—2—13	15	290.7	9.193	3.16	2.0	5.8	1.12	1.56	....	....
	Average for 29 7-day tests	....	....		32	313.8	10.56	3.36	1.5	7.0	.75	2.26	101.7	96.4—4.6

[1] Two observations. [2] Twelve-day test: 549.0 lbs. milk, 15.27 lbs fat, 2.78 per ct. fat. [3] Twelve-day test: 603.7 lbs. milk, 14.65 lbs. fat, 2.42 per ct. fat. [4] Two-day test. [5] Temperature taken first day only.

	Class IV.—Cows under three years old.													
79	Laura Welcome	43,498	Aug. 22	2— 9—26	7	329.1	11.415	3.47	2.8	4.2	1.54	1.72	....	....
80	Joh. B's De Kol Clothilde	49,456	Aug. 22	2— 0—26	52	234.2	6.557	2.80	2.3	3.6	.77	1.02	....	....
81	Bessie Ward Tritomia	44,128	Aug. 30	2— 8— 9	4	241.5	8.[illegible]71	3.55	2.85	4.2	.06	1.46	....	....
82	Johanna Rue 4th	45,166	Dec. 7	2— 2—17	59	317.8	11.317	3.56	3.2	4.0	1.58	1.65	....	....
83	Hartzog Neth. Inka Pietertje	44,781	Dec. 20	2— 3— 3	12	339.9	10.650	3.13	2.3	4.1	1.43	1.66	....	....
84	Almeda Tritomia	44,129	Dec. 20	2— 1—10	19	237.0	8.385	3.54	2.9	4.4	.94	1.37	....	....
84	Jessie Fobes 2d Myrtle	49,192	Dec. 20	2— 2— 3	6	226.5	6.518	2.88	2.3	4.0	.78	1.08	....	....
86	Neth. Johanna Rue	46,877	Jan. 4	2— 4— 0	56	257.2	7.891	3.07	2.15	4.05	.98	1.23	101.9	101.6—2.0
87	May Ormsby	46,453	Jan. 12	2— 5—29	112	228.1	7.541	3.31	2.6	4.2	1.00	1.16	101.6	101.1—2.7
88	Aaggie Gerben	46,373	Jan. 19	2—11— 4	23	319.1	9.310	2.92	2.3	4.0	1.24	1.37	102.1	101.7—2.7
89	Aaltje Solo 5th Trit. 3d	43,982	Jan. 19	2—11— 2	89	220.6	8.036	3.64	3.0	4.8	1.02	1.24	101.2	101.0—1.5
90	Busacker	43,980	Jan. 19	2—10—29	79	211.5	7.308	3.46	3.1	4.0	.98	1.08	101.3	100.8—1.6
91	Netherl. Minnie	46,876	Jan. 19	2— 3—18	95	192.8	6.326	3.28	2.7	4.0	.86	.97	101.6	101.4—2.0
92	Johanna Wit	44,785	Jan. 19	2— 9— 1	73	189.0	6.609	3.50	2.3	5.6	.84	1.09	102.0	101.3—2.7
92a	Aaltje Salo Princess May	43,981	Jan. 26	2—11—27	22	245.9	8.835	3.58	2.5	4.67	1.05	1.68	101.3	101.0—1.7
93	Piebe Queen 2d Princess	45,007	Feb. 13	2—10—28	21	288.9	10.028	3.47	2.9	4.81	1.34	1.54	....	....
94	Johanna De Kol	45,167	Apr. 1	2— 3—15	3	289.1	12.523	4.33	2.95	5.2	1.73	1.86	102.1	101.9—2.4
			May 17	2— 5— 0	51	330.3	11.367	3.44	2.0	4.6	1.55	1.82	....	....
95	Orphan Maid 2d	46,452	Apr. 3	2— 9— 0	302	177.4	6.803	3.80	3.2	4.55	.37	1.06	101.5	100.4—4.1
			May 29	2—10—24	358	220.2	6.752	3.07	2.6	3.4	.90	1.01	101.9	100.8—3.2
96	Lottie Dougl. 2d Pride	44,769	Apr. 4	2— 5—11	61	249.0	7.932	3.22	2.7	3.8	1.05	1.30	101.6	101.3—1.8
97	Jessie Maida	48,805	Apr. 15	1—10— 0	42	264.2	7.989	2.94	2.4	3.5	1.04	1.24	102.2	101.8—2.5
98	Minnie Sandes	49,518	Apr. 15	1—10—24	30	262.2	8.093	3.09	2.2	3.8	1.11	1.20	102.4	102.0—3.0
99	Johanna Aaggie 2d	45,165	Apr. 22	1—11—15	8	253.3	9.178	3.62	3.0	4.4	1.28	1.36	[1]101.9	101.8—1.9
			May 17	2— 0—10	33	285.5	10.164	3.55	2.6	4.5	1.34	1.55	....	....
100	Ollie Watson	48,168	May 10	2— 0—20	26	235.4	7.796	3.31	2.9	4.1	1.07	1.17	102.1	101.2—2.5
101	Gewina Lulu Snowball	48,169	May 10	2— 1— 2	30	203.8	7.609	3.73	2.5	4.8	.91	1.16	102.4	101.2—3.5
101	Gewina Beauty Bell	48,167	May 10	2— 1—22	49	257.9	7.961	3.09	2.4	4.0	1.00	1.22	102.0	101.0—4.0
103	Aaltje Salo Aag. 2d [2]	46,798	May 20	2— 6—29	226	233.1	8.010	3.44	3.2	3.8	1.10	1.17	101.0	98.0—2.0
104	Akkrummer Elenera [3]	46,796	May 20	2— 3— 3	149	231.0	7.727	3.34	3.0	3.6	1.01	1.15	....	....
105	Butterfly Netherland	48,760	May 29	2— 0—29	52	247.9	6.483	2.61	2.3	3.0	.87	.96	101.6	101.0—2.4
106	Bell Captain Mechthilde	50,186	June 8	1— 6—16	199	306.7	8.847	2.88	2.4	3.4	1.18	1.43	100.7	100.0—1.5
107	Schoone Princess De Kol	46,799	June 24	2— 7— 0	7	297.7	8.886	2.99	2.4	3.8	1.19	1.38	102.1	102.0—3.2
108	Paula S. M	49,160	July 3	1—11—12	12	218.9	7.561	3.45	2.6	4.6	1.04	1.12	....	....
	Average for 34 7-day tests	....	....		**70**	**254.2**	**8.44**	**3.33**	2.0	5.6	.78	1.86	101.8	98.0—4.1

[1] Temperature taken first two days only.
[2] Ten-day test: 329.8 lbs. milk, 11.177 lbs. fat, 3.39 per ct.
[3] Ten-day test: 304.5 lbs. milk, 10.224 lbs. fat, 3.36 per ct. fat.

It is a source of gratification to us to note that a large proportion of the prizes offered for these tests by the Holstein-Friesian Association of America for the year 1899–1900 went to cows tested by this Station, whose records are given above. First prizes were awarded to cows Nos. 3 and 94; a second prize to No. 44; a third prize to No. 48; fourth prizes to Nos. 43, 72 and 83; sixth prizes to Nos. 24, 71 and 79; a seventh prize to No. 58; an eighth prize to No. 23, and an eleventh prize to No. 15. Sixteen out of sixty-three prizes offered by the Association for officially authenticated records, 1899–1900, were given to cows tested by this Station, all of which, with only a few exceptions, were owned by Wisconsin breeders. This does not include the prizes awarded to cows entered in the economical food tests of this Association, which are given below.

Economical food tests.—The following cows were entered in the economical food tests of the Holstein-Friesian Association, with the results given; the numbers of the different cows are the same as in the preceding tables. The schedule of prices of products and food stuffs are published in the report of the Holstein-Friesian Association.* The results reported are for a period of seven days, and are testified to under oath by our Station representative and the owners of the cows.

Economical food tests of Wisconsin cows, 1899–1900.

Class	No.	Name.	Registry No.	Yield of butter, lbs.	Cost of food.	Cost of Food Required for Producing 100 lbs. milk.	Cost of Food Required for Producing 1 lb. butter.	Net profit.
I...	3	Colantha 4th	35,028	19.592	$1.30	25.3	5.3	$1.338
	4	Johanna De Kol	36,478	15.498	1.08	26.4	5.6	3.384
	16	Bell Pentaur	20,361	12.675	1.52	38.2	9.6	2.130
	19	Rose Aaggie Liddisdale	1,413*	13.695	1 23	29.2	7.2	2.804
	26	Johanna Aaggie	36,477	16.870	.98	24.3	4.6	3.818
	27	Nina Melchior	24,500	12.529	.68	21.3	4.4	2.912
II....	44	Johanna Clothilde	40,384	14.059	1.09	31.1	6.2	2.93
III.	55	Johanna De Pauline	42,169	14.971	.89	27.4	4.7	3.32
	56	Johanna Rue 3rd	42,167	15.204	1 05	25.5	5.9	3.348
	63	Fanny Douglas 4th	41,943	10.130	1.20	37 4	8.7	1.796
	68	Rijanetta Clothilde	42,949	13.612	.69	23.0	4.1	3.142
IV.	82	Johanna Rue 4th	45,166	11 317	1.05	33.2	7.5	2.235
	94	Johanna De Kol 3d	45,167	12 523	.63	21 8	4.0	2.916
	99	Johanna Aaggie 2d	45,165	9.179	.74	29.2	6.4	1.922

* Western H.-F. Herd Book.

* Condensed report of annual meeting, Buffalo, June 6th, 1900.

The following prizes for records of net profit were awarded to cows in the preceding table: First prizes, cows Nos. 3, 56 and 94; second prizes, cows Nos. 44 and 55; third prizes, cows Nos. 26, 58 and 82; a fourth prize, cow No. 99; a fifth prize, cow No. 54; a sixth prize, cow No. 63; a ninth prize, cow No. 27; an eleventh prize, cow No. 19; a twelfth prize, cow No. 16. Out of twenty-four prizes awarded on the economic food-tests, 1899–1900, fourteen were given to cows tested by this Station, all but one of which were owned by Wisconsin breeders.

B. TESTS OF GUERNSEY COWS.

The tests of Guernsey cows conducted by this Station were made in accordance with the general rules governing official tests since May, 1900; prior to this time the Station tested once a month a composite sample of milk of the cows entered in the Guernsey Home Tests, the weighings of the milk of the cows and the composite samples being taken by the owner himself. The breeders in this state who entered their cows in these tests were Geo. C. Hill & Son of Rosendale, Wis., and James H. Beirne of Oakfield, Wis. Regular monthly tests of the milk of five cows in the former herd, and of two cows in the latter herd were made; the following cows finished a year's record in these tests during the past year; cows Nos. 1 and 2 are owned by Mr. Beirne, and the others by Geo. C. Hill & Son.

Results of Guernsey home butter tests, 1898–99.

No.	Name.	Regis-try No.	Age.	Date of calving.	Milk.	Butter fat.	Butter.	Average per ct. fat.
			Yrs.	1898.	Lbs.	Lbs.	Lbs.	
1	Lily Ella..........	7,240	5	Dec. 7...	12,282.68	782.16	912.5	6.42
2	Lilyita............	7,241	5	Dec. 7...	12,812.73	710.53	828.95	5.69
3	Countess Bishop.	7,869	4	Mar. 20...	7,387.3	452.23	527.71	6.42
4	Madame Tricksey	6,519	6	Apr. 14...	7,024.6	405.19	472.71	5.85
5	Lady Bishop......	6,518	7	Mar. 29...	6,608.9	381.1	444.63	5.40
6	Pristoun..	6,570	7	Nov. 26...	6,868.3	355 68	414.95	5.19
7	Nounon...........	6,569	9	Mar. 24...	6,338.0	351.7	410.31	5.51

Cows No. 1, 2, and 3 received first, second, and third prizes, respectively, offered for individual yields by the American

Guernsey Cattle Club, 1898–'99, while cows No. 3-7, inclusive, were awarded first prize for herds of five cows each.

The monthly tests made by the Station, November, 1898, to October, 1899, are given on page 151 of our 16th Annual Report; it was stated in this place that check-tests of the two cows Lily Ella and Lilyita, were taken four times during the year by disinterested parties, and we have every reason to believe that the annual records as published by the Association are correct.

The rules governing the Guernsey test during the current year from May, 1900, were modified to the extent, that weighings and tests of the milk of cows entered will be made for a full day once every month by an Experiment Station officer, or a representative of our Station. Seven cows in each of two Wisconsin herds were accordingly tested by us May to July, inclusive, this year; one of the breeders withdrew at the end of this period, and the only breeders in this state that now take part in the tests are Geo. C. Hill & Son of Rosendale, Wis. The results of the monthly weighings and tests of the milk of cows in this herd will be published when the year's records have been completed.

C. OFFICIAL TESTS OF SHORTHORN COWS.

Two Shorthorn cows were tested during the past year, both belonging to W. S. Carpenter, Menominee, Mich. The tests were conducted by Chas. A. Nicolaus, as our Station representative, with results as shown below:

Name.	Age.	Test began.	Days in milk.	Milk.	Fat.	Per ct. fat.		Fat per day.	Temp. of cow.	
						Av.	Range.	Range.	Av.	Range.
	Yr. Mo.	1900		Lbs.	Lbs.			Lbs.	° F.	° F.
Reddie 1st....	2—6	Feb. 8	8	205.4	7.073	3.44	2.9—4.2	.97 - 1.05	101.8	101.5—2.0
Reddie 1st....	2—6	Feb. 15	15	209.4	7.493	3.57	2.8—4.3	1.03—1.12	[1]100.5	101.3—1.6
Reddie 2d [2]...	2—6	Feb. 15	9	207.9	7.435	3.58	2.7—5.0	.94—1.14	101.9	101.8—2.1

[1] Two observations only.

[2] Nine-day test: 259 lbs. milk; 9.30 lbs. fat; 3.59 per ct. fat.

D. OFFICIAL TESTS OF RED POLLED COWS.

Eight Red Polled cows were tested during the year, two belonging to J. L. Sanderson, Centreville, Wis. (Nos. 1 and 2), and six belonging to Arthur Dutton & Son of Centreville, Wis. (Nos. 3-8). The tests were conducted by E. G. Hastings, Assistant Bacteriologist of the Station, and were for two full days:

Official tests of red polled cows.

Cow No.	Name.	Registry No.	Test began.	Age.	Days in milk.	Milk.	Fat.
			1900	Y. M. D.		Lbs.	Lbs.
1	Nora	11,648	May 22	3	158	50.5	1.830
2	Jule	11,378	May 22	4	68	70.7	2.512
3	Duchess of Centerville	5,424	May 24	10—8—0	101	67.1	2.497
4	Rosette	8,941	May 24	7—5-13	169	44.4	1 774
5	Hetty 2d	11,341	May 24	10—0—18	141	42.4	1.751
6	Honor 3d	11,347	May 24	11—2—19	147	45.7	1.545
7	Violet Cone	12,372	May 24	2—5—21	31	47.0	1.980
8	Joyce	8,624	May 24	7—3-18	119	51.2	1 689

Official tests of red polled cows — Continued.

Cow No.	Name.	Per Cent Fat.		Fat Per Day.	Temp. of Cow.	
		Average.	Range.	Range	Average.	Range.
				Lbs.	° F.	° F.
1	Nora	3 63	3.4 -3.65	.91- 92	101.8	101.5- 2.1
2	Jule	3.55	3.38-3.8	1.19-1.32	101.5	101.5- 1.6
3	Duchess of Centerville	3.72	3.35-4.05	1.16-1.34	101.8	101.5- 2.0
4	Rosette	4.00	3.45-4.57	.85- .92	101.0	101.0-101.0
5	Hetty 2d	4.13	3.97-4.4	.86- .89	101.0	100.9- 1.0
6	Honor 3d	3.38	3.0 -3.9	.77- .77	102 0	101.5- 2.5
7	Violet Cone	4.21	3.75-4.9	.97-1.02	101.8	101.5- 2.0
8	Joyce	3 30	3.1 -4.25	.83- .86	100 8	100.7- 0.9

INFLUENCE OF THE BABCOCK TEST.

I. A SOURCE OF ERROR IN SOME TURBINE TESTERS.

F. W. WOLL.

Last winter when making comparative analyses of composite samples of milk of pure-bred cows, the writer was surprised to find that the results obtained for the same samples by the Babcock test and by gravimetric chemical analysis failed to agree, the former coming uniformly higher than the latter. The differences found were appreciable, amounting to from one- to three-tenths of 1 per cent., according to the quality of the milk, the greatest differences being found in case of the richer milks. Feeling certain of the correctness of the results of the Babcock tests, I first looked for an error in the gravimetric analyses, which were made by the so-called Babcock asbestos method.* Nearly all of the samples were preserved with potassium bichromate, and it seemed reasonable to suppose that the bichromate, through its toughening effect on casein, might cause the latter to protect the fat from being entirely dissolved by ether, or but very slowly so. The asbestos-copper tubes were, therefore, put back in the fat-extraction apparatus and subjected to a second extraction. While a small increase in fat was often thus obtained, in no case was it sufficient to bring the per cent. of fat up to the amount which, according to the Babcock test, should be found in the sample. In some cases the first extraction was continued for twelve hours, and a second extraction for six hours.

* Methods of analysis adopted by the Association of Official Agricultural Chemists, bull. 46, rev. edition, Division of Chemistry, U. S. Department of Agriculture, p. 54.

The manipulation of the Babcock test and the tester were next subjected to a critical examination, and it was soon discovered that the source of the error lay in the Babcock tester which was used in these analyses. This was one of the standard steam turbine testers on the market, and the test bottles in this machine were always very hot on the completion of the tests; considerable steam enters the upper compartment of the tester during the whirling, and there is no chance for this to escape or to be mixed with cold air so as to temper the heat to which the bottles with contents are exposed. The expansion of the fat at the high temperature in the tester was evidently the cause of the high results. To ascertain the facts of the case, tests of the same milks were made by chemical analysis, in different turbine testers, and in acouple of hand testers. The results obtained by chemical analysis and by the use of the hand testers always agreed, as has been generally the case, within a tenth of 1 per cent.; sometimes higher, and sometimes lower than the gravimetric results. A couple of the steam turbine testers tried also gave results corresponding closely to chemical analysis, but most of them,—and unfortunately among them some of the testers recently placed on the market that are mechanically our most perfect machines,—gave too high results. Furthermore, bottles that were whirled in hand testers and had given correct results, when afterwards placed in a turbine tester for a few minutes, with steam introduced into the upper part of the tester, would invariably read one- or two-tenths higher when taken out than they did before. These differences occurred with ordinary grades of milk. With very rich milk and with cream the differences observed were considerably greater, and in cream of average quality, amounted to one per cent. or more.

A few comparative determinations may be given to show the differences that are apt to occur when tests of milk are made with different testers on the market at the present time.

Comparative fat determinations in milk.

Sample No.	Gravimetric analysis.	Turbine No. 1.	Turbine No. 2.	Turbine No. 3.	Turbine No. 4.	Hand tester.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1	3.51	3.65	....	....	....	....
2	3.96	3.65	....	....	....	....
3	4.03	4.25	....	....	....	....
4	2.93	3.03	....	....	....	....
5	5.14	5.30	....	....	....	....
6	5.08	5.35	....	....	....	....
7	4.62	4.78	....	....	....	....
8	3.31	3.35	3.25	3.35	....	3.20
9	3.93	4.13	3.98	4.20	....	3.99
10	3.75	4.00	3.85	4.95	....	3.85
11	4.55	3.65	3.58	3.65	....	3.56
12	....	3.21	3.30	....	....	3.03
13	....	4.96	4.95	4.84	4.83	4.83

Each of the preceding results are averages of two or more determinations and are taken at random from my records; the data given will suffice to show the errors introduced by some turbine testers. As already stated, the high Babcock tests obtained were due to the expansion of the fat at the high temperature in some of the turbine testers. It was found that this often reached 200 degrees F. The range of temperatures at which readings in hand testers are made is given by Dr. Babcock in the original description of the Babcock test* as from 110 to 150 degrees F., or 40 degrees; in "Testing Milk and its Products" (by Prof. Farrington and the writer),† we have shown that this extreme difference corresponds to about .07 per cent. of fat in case of a five per cent. milk, and the average error due to differences in the temperature of the fat would therefore be less than .04 per cent. If we assume that the readings in hot turbine testers are taken at 200 degrees, the temperature is perhaps 90 degrees higher than necessary, and the fat column will therefore have expanded at this temperature so as to fill a space that is .16 per

* Seventh report, Wis. Experiment Station, p. 107.

† 6th ed., page 37, foot note.

cent. too high in case of a 5 per cent. milk, and .11 per cent. too high in case of a 3 per cent. milk.

The differences found in case of turbines Nos. 1 and 3 are therefore fully explained by the expansion of the fat column at the high temperature at which readings are taken in some of the turbine testers. Turbines Nos. 2 and 4, on the other hand, gave results that generally correspond with chemical analyses, or with tests made in hand testers; in neither of these does the temperature go much above 150 degrees; in case of No. 2, on account of the opening in the cover around the shaft which admits considerable cold air to the tester while in motion. No. 4 is one of the first turbines put on the market and has a large copper drum and a copper lid that is bent and does not fit well.

The error in tests made in hot turbine testers becomes especially noticeable when samples of cream are tested. Theoretically the maximum error introduced by a too high temperature in the tester in case of cream testing will amount to .80 per cent. for a 25-per cent. cream, .96 per cent. for a 30-per cent. cream, and 1.12 per cent. for a 35-per cent. cream. The analyses made have shown that the fat contents in rich cream tested in hot turbine testers come toward 1 per cent. too high, the error increasing with the richness of the cream. The following comparative tests are here given:

Comparative fat determinations in cream.

Sample No.	Gravimetric analysis.	Turbine No. 1.	Turbine No. 2.	Turbine No. 3.	Turbine No 4.	Hand tester.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1	....	22.85	....	....	....	21.80
2	22.39	23.04	23.03	....	....	22.36
3	23.45	21.85	....	25.27	23.68	23.83
4	31 25	36.10	....	....	37.67	34 30
5	33.09	33.92	....	....	33.69	....
6	....	....	....	35.22	33.53	33 93

In the first sample tested the cream was measured with a 17.6 cc. pipette; in the other tests it was accurately weighed on an analytical balance.

The question of the temperature at which readings should be taken in Babcock testers has apparently received little or no thought from manufacturers of turbine testers, as I have had occasion to ascertain through correspondence with the leading manufacturers. They seem to have worked on the principle that the more heat the better, and still a few comparative trials will convince anyone that an excessive temperature in the tester is a disadvantage in every way, except one, that the readings can be postponed a little longer when a very high temperature is maintained in the tester; but the disadvantages are much greater: the readings taken under these conditions are never perfectly clear and distinct, there being always more or less black, flocculent matter in or directly below the fat column, or foam on top of it; the bottles are very hot and therefore difficult to handle as taken out of the tester, and owing to the rapid cooling of the bottles when taken out, the fat column will at once sink perceptibly in the neck of the bottles, thus rendering the readings more uncertain.

The manufacturers will doubtless remedy the difficulty mentioned when their attention has been called to the matter. This can fortunately be easily done by shutting off so far as possible the supply of steam into the upper compartment of the tester, and by allowing a current of air to enter the tester through the cover while the bottles are whirled. There are, however, a large number of testers in factories and private dairies at the present time that are giving too high results, and they will be used for many years to come. In order to have correct tests in these machines the bottles must be allowed to cool to about 140 degrees before readings are taken, either by leaving the cover of the machine off for a couple of minutes or by placing the bottles in water of this temperature for a few minutes. No readings should of course be taken when the fat in the neck of the bottles is beginning to solidify, but neither should the temperature at which readings are taken be allowed to go above 150 degrees F. if the method of reading the column of fat originally recommended by Dr. Babcock be followed, as is on the whole advisable to avoid confusion.

In order to know whether or not a turbine tester gives too high results it is only necessary to ascertain the temperature at which

bottles are heated after four minutes' whirling. This should not, as already stated, exceed 140–150 degrees Fahr. A practical rule may be given, that if the fat column in the neck of the bottle sinks rapidly when this is taken out on completion of the test, or if the bottles are too hot to be held in one's hand without difficulty, the readings are likely to be from one- to two-tenths of 1 per cent. too high with milks of ordinary quality, and in such cases the fat should be allowed to cool to about 140 degrees before readings are taken.

II. INFLUENCE OF TEMPERATURE ON TESTS OF SKIM MILK BY THE BABCOCK TEST.

E. H. FARRINGTON.

Among chemists it is a well-known fact that duplicate gravimetric analyses of skim milk, and, in fact, analyses in general, do not agree exactly on account of unavoidable errors of analysis, and chemists are quite well satisfied with their work if duplicates agree within .03 of one per cent. If a chemist makes two analyses of one sample of milk, and his results are 4.25 and 4.28 per cent. fat, he is convinced that his work is as accurate as can be reasonably expected. He is just as well satisfied with these figures as he would be with 4.25 and 4.25 per cent. A chemist does not repeat his analyses until duplicates show exactly the same figure. He knows that a perfect agreement of results is more likely to be an accident than evidence of his care and skill.

Since chemists accept duplicate results that differ as much as .03 per cent. there is very little ground for a claim of better skimming by a separator whose skim milk tests are reported as, e. g., .01 over others showing a content of .04 per cent. fat. Microscopic examinations of the acid liquid in the bulb of test bottles have shown that some minute fat globules are not separated by the whirling. These globules remain in the bulb of the test bottle, because the centrifugal force has not been sufficient to separate them. This residual fat was noticed by Dr. Babcock,

and mentioned in his early descriptions of the test. It amounts to a much larger part of the total fat in skim milk than of that in whole milk, and in making tests of skim milk, the operator should keep this in mind and make every effort possible to separate as many of these minute globules as he can.

The influence which the speed of the tester has on the completeness of the fat separation has long been recognized, and the highest speed possible with safety to the machine and glass test bottles is recommended. There is another factor, however, that aids in separating these minute fat globules besides centrifugal force, viz., the temperature of the liquid in the test bottles.

The Babcock machines now commonly used are hand testers and steam turbine testers. In the hand machines the temperature of the test bottle does not ordinarily rise during the whirling, but in some of the turbine testers the bottles are heated to the temperature of the exhaust steam which approaches that of boiling water. At the present time the steam turbine tester is very extensively used, nearly every manufacturer of dairy supplies having placed such testers on the market. These testers do not differ very much in their general construction, but there is one important difference, viz., in the construction of the cover.

One style of tester is made with a tightly closed cover, one-half of which opens while the other half is fastened to the tester frame. Near the center of the stationery half of this cover there is a bearing for the shaft of the revolving wheel which supports the test bottle cups.

The other style of tester is made without attaching the shaft to the cover, but around the top of the shaft is a circular opening in the cover. This opening makes a great difference in the temperature of the test bottles during a test. A current of cold air is drawn into the upper compartment through the opening in the cover in one style, and forces the steam out of the test bottle chamber into the exhaust pipe, while in the tightly closed testers there is no draft of air and the test bottles are heated to the temperature of the steam which accumulates in the machine. I have noticed a difference of 60° F. in the temperature of the test bottle chambers of these two styles of testers. In one having a tightly closed cover, the temperature may reach 200° F., while

in another tester having the opening in the cover the temperature is generally about 140° F. This temperature of 140° F. is about right for reading the fat in the necks of the test bottles, but when they are heated to 200° F. or higher and readings made at this time, Prof. Woll has shown (see p. 76) that the tests of whole milk are exaggerated by the expansion of the fat in the necks of the test bottles.

The errors caused by this expansion can be easily overcome by placing the hot test bottles in water at 140° F. for about ten hours before the readings are made.

Although this high temperature is to be guarded against in tests of whole milk it occurred to the writer that it was just what is needed for separating the minute globules of fat in testing skim milk. The amount of fat in separator skim milk is generally not sufficient to cause any inaccuracy in the readings on account of its expansion at this high temperature, therefore 200° F. is not too high for separating or for reading the fat in skim milk containing in the neighborhood of one-tenth of one per cent. of fat.

In order to test the accuracy of this assumption a number of samples of separator skim milk were examined in three different ways.

1st. Careful gravimetric analyses were made by extraction with ether and weighing the fat. About 10 c. c. of the sample was weighed into a perforated copper tube filled with asbestos; the asbestos had been previously digested with acid, washed and dried in the usual way, and each tube full of asbestos was extracted with ether for at least four hours before using it for the skim milk analysis. Two extractions for a period of six hours each were made of the dried skim milk solids. There is so little fat in such skim milk that accurate gravimetric results can only be obtained when these precautions are taken.

2nd. Tests were made with the double necked skim milk bottles, using at least 20 c. c. of acid for each test and whirling the bottles in a turbine tester which had an opening in the cover that prevented the bottles from being heated much above 140° F.

3rd. Test bottles were also whirled in a turbine tester having a closed cover, and were heated to about 200° F. during the whirling.

Each sample was tested in duplicate by the three methods, and the results obtained are given in the following table. All the figures are given so that the difference between duplicates by the same method may be noticed:

Table showing gravimetric analyses and Babcock tests of skim milk.

SAMPLE No.	PER CENT. FAT.					
	Gravimetric analysis.		Steam turbine testers.			
			Closed cover temperature 200 F.		Opening in cover temperature 140 F.	
	Separate.	Average.	Separate tests.	Average.	Separate tests.	Average.
1	.068—.068	.07	.06—.07	.07	.03—.03	.03
2	.088—.088	.08	.07—.08	.08	.04—.04	.04
3	.068—.078	.07	.05—.05	.05	.02—.02	.02
4	.087—.078	.08	.06—.07	.07	.03—.04	.04
5	.058—.068	.06	.05—.05	.05	.02—.03	.03
6	.048—.078	.06	.05—.02	.04	.02—.03	.03
7	.094—.066	.08	.05—.05	.05	.02—.03	.03
8	.078—.051	.07	.04—.04	.04	.02—.03	.03
9	.096—.12	.11	.05—.05	.05	.03—.02	.03
10	.09 —.10	.10	.05—.05	.05	.03—.03	.03

These results show, *First,* that in every case the tests were higher when made in the tightly-closed tester and heated to about 200° F. than they were when tested in the machine having an opening in the cover and whirled at about 140° F. In some cases twice as much fat was shown in the hot test bottles as in the others.

Second, a reasonable agreement of duplicate tests is not always positive evidence of correct results. In nearly every sample the duplicates in one machine agreed very closely, but the tests made at 200° F. were nearly twice as high as those made at 140° F.

Third, tests of skim milk made with 20 c. c. of acid and whirled at a high speed in a machine heated to about 200° F. give results nearer those obtained by gravimetric analysis than are obtained by any other method.

Fourth, results reported as .01, .02, .03, or anything less than .05 per cent. fat in skim milk, are an indication of defective

testing. The operator may be entirely innocent of his error, but careful attention to the speed and temperature during testing will often aid in increasing the per cent. of fat in skim milk. It follows from what has been said that readings given as one-half of one hundredth of one per cent. are absurd.

These results, together with those of Prof. Woll, show that the turbine tester in which bottles are heated to 200° F. gives too high results when whole milk is tested but more nearly correct results on skim milk. The turbine tester, however, which has an opening in the cover so that the temperature does not rise much above 140° F. gives results too low on skim milk but correct with while milk.

Instead of using two testers, a combination of the advantages which each of these machines possesses may be made in one tester by boring one-inch holes in the cover of the tightly closed tester and arranging a sliding damper by means of which these holes can be opened when whole milk is being tested and closed for skim milk tests. This will regulate the temperature of the test bottle chamber by controlling the draft of air through it. A place for a thermometer can also be made near the center of the cover.

A turbine tester constructed in this way will have the advantages of an upper bearing, which helps to give a steady motion to the revolving bottles; it will also be possible by opening the holes in the cover to prevent the whole milk tests from becoming too hot and by closing them to aid the separation of fat in skim milk tests by increasing the temperature.

I have repeatedly made tests of skim milk in the two styles of turbine testers mentioned, and nearly always find more fat in the bottles whirled in the hot tester than in one having an opening in the cover.

The hot test bottles were placed in water at 120° F. after whirling in the machine and no contraction of the fat was noticeable, showing that the increase of fat in the hot skim milk tests was not due to an expansion of the fat by the heat, but that this high temperature aided in separating more of the minute fat globules than was obtained when the test bottles were whirled at a lower temperature.

I have never yet tested a sample of skim milk in the double neck bottles, when 20 c. c. of acid was used and the bottles were whirled at a sufficient speed and kept hot during the whirling, that showed less than four or five hundredths of one per cent. of fat on the scale of these bottles.

III. THE ESTIMATION OF FAT IN SWEETENED CONDENSED MILK BY THE BABCOCK TEST.

E. H. FARRINGON.

The Babcock Test is now a standard method for the estimation of butter fat in nearly all kinds of dairy products. It is universally used for examining whole milk, skim milk, butter milk, whey, and cream, and it has also been successfully applied to the determination of fat in cheese and in condensed milk containing no sugar. A large proportion of the canned condensed milk, however, is sweetened with cane sugar and up to the present time no satisfactory way of testing this sweetened milk has been devised. Instead of the clear fat, a black floculent substance separates in the neck of the test bottles, and when the test is carried out in the usual way it is impossible to obtain a satisfactory reading with such milk.

Many attempts have been made to obtain a clear fat separation by using more or less acid, or acid of different strengths, but these modifications have not overcome the difficulties. The common way of determining fat by ether extraction of the sweetened condensed milk is also unreliable, so that chemists have not had any very satisfactory method for estimating the fat in condensed milk to which sugar has been added.

Since it is evident that the excess of cane sugar is responsible for this poor separation of the fat, some way of removing this sugar must be devised in order to make any method of analysis successful. This I have found can be done by a few changes in the ordinary manipulation of the Babcock test.

In order to wash out the sugar without removing any of the fat in the washings I first had a test bottle made with two necks.

One of these is the usual graduated neck and the other is a side tube of about the same bore and fully as long as the neck tube, but extending to the bottom of the test bottle. By means of this side tube the sugar solution can be syphoned out of the test bottleafter the curd has been separated with a few drops of acid.

A number of trials with this test bottle showed that the excess of sugar could be removed in this way and that a clear separation of the fat is afterwards obtained by completing the test in the usual manner. It soon became evident, however, that the side tube was superfluous and that the whey could be poured off from the curd through the graduated neck of the test bottle as safely as it was syphoned through the side tube. This is made possible by whirling the test bottles in a steam-heated centrifuge at such a speed that the curd is cooked into a rather hard lump which does not break when the whey is poured off.

A brief description of the manipulations adopted will explain the method that has proved satisfactory.

From forty to sixty grams of condensed milk are weighed into a 200 c. c. graduated flask; about 100 c. c. of water are added and the solution of the condensed milk effected. The flask is then filled to the mark with water and after mixing thoroughly, a 17.6 c. c. pipette full is measured into a Babcock test bottle. About three c. c. of the sulfuric acid commonly used for testing milk are then added and the milk and acid mixed by shaking the bottle vigorously. The milk is curdled by the acid, and the curd and whey separated somewhat. In order to make this separation complete and to compact the curd into a firm lump, the test bottle is whirled for about six minutes at a rather high speed (1,000 rev.) in a steam-heated turbine centrifuge.

The chamber in which the bottles are whirled ought to be heated to about 200° F. This can be done either by the turbine exhaust steam which leaks into the test-bottle chamber of some machines, or by means of a valve and pipe which will allow steam to be turned directly into the test bottle chamber. After this first whirling the test bottles are taken from the centrifuge and by being careful not to break the lump of curd nearly all the whey or sugar solution can be poured out of the neck. Ten c. c. of water are then poured into the test bottle and the curd

is shaken up with it so as to wash out more of the sugar. Three c. c. of acid are now added as before and the test bottle whirled a second time in the centrifuge. The whey is decanted again and this second washing removes so much of the sugar that what remains will not interfere with testing in the usual way. The curd remaining in the test bottle after the second washing is shaken up with ten c. c. of water and to this water emulsion of the curd the usual amount, 17.5 c. c., of sulfuric acid is added and the test completed in the same way as milk is tested. The amount of fat finally obtained in the neck of the test bottle is calculated to the weight of condensed milk taken.

Several analyses of the same sample were made using a different weight of condensed milk each time. The results when calculated to the original substance gave in all cases practically the same percentage of fat.

Five brands of sweetened condensed milk were examined by this process, at least four determinations being made of each sample. The fat separated was clear and the final results satisfactory.

Sixty grams of the condensed milk is about the right amount to take in a 200 c. c. flask; each 17.6 c. c. pipette full of this 200 c. c. is then equal to 5.28 gr. of the sample tested. The common brands of condensed milk will give a reading from this weight, of about 2.0 per cent. on the neck of a Babcock test bottle. The volume of fat occupied by one per cent. on the scale of the test bottle is equal to .18 gr. fat; and 2 per cent. would show .36 gr. fat, which is 6.81 per cent. of the 5.28 grams condensed milk tested.

If only 20 gr. condensed milk is measured into a 200 c. c. flask a difference of two-tenths of one per cent. fat in the neck of the test bottle amounts to about two per cent. fat in the original substance. It is, therefore, well to test a more concentrated solution of the milk than this.

The following results were obtained with the five samples examined. Each sample was tested four or more times with a very satisfactory agreement of results in each case.

Sample No.	Weight and dilution of condensed milk tested.	Test bottle reading.	Per cent. fat in condensed milk.
No. 1..........	60 gr. to 200 c. c..........................	2.4	8.00
No. 2.........	29.6 gr. to 200 c. c..........................	1.25	8.00
No. 3..........	32.7 gr. to 200 c. c..........................	1.6	10.00
No. 4.........	51 6 gr. to 200 c. c..........................	2.4	9.30
No. 5..........	45 4 gr. to 200 c. c..........................	2.3	10.35
No. 6..........	65 8 gr. to 200 c. c..........................	2.0	6.35

The condensed milk may be transferred to the weighed measuring flask by means of a glass funnel which reaches to the bulb of the flask, pouring the thick liquid previously mixed with a spatula, directly from the tin can into the funnel through which it will run gradually if the throat of the funnel is large enough.

Careful tests of the whey poured off from the test bottles showed that no fat was lost by this decantation if the whey was clear and contained no pieces of curd. It is very essential that the curd should be cooked in the test bottle so as to shrink it into a compact lump which does not break when the whey is poured off.

CALCULATING DIVIDENDS FOR MILK AND FOR CREAM AT THE SAME FACTORY.

E. H. FARRINGTON.

The amount due farmers for their milk at separator creameries is now universally determined by means of the Babcock Test. As a rule the gathered-cream factory is supplied with cream only and the separator creamery with milk only, but there is a constantly increasing number of places where both are received. The method of calculating whole milk dividends is very generally understood, but when some farmers supply cream instead of milk the payment for both on a butter fat basis is somewhat more complicated. During the past year many inquiries have been received from farmers in regard to this matter. Some farmers have bought hand separators and are now sending cream instead of milk to the factory, and they rightly think that their cream dividends should be calculated in a somewhat different way from the milk dividends.

The more progressive gathered-cream factories have dropped the system of measuring cream by the inch and grading it with the old oil test churn. Their cream haulers are now provided with scales and sampling bottles and each lot of cream is weighed, sampled and tested by the Babcock test, in the same way as milk is received and tested at separator factories.

The Babcock test has shown that an inch of cream from one patron may, in some cases, make three times as much butter as an inch of cream from some other patron. It has also been noticed that an inch of cream from the same farm on different days will not contain the same amount of butter fat. The Babcock test, with composite samples of cream, has proved to be a satisfactory and accurate method of ascertaining how much money is due each patron at gathered-cream factories. A de-

tailed description of the manner in which it is now successfully used at these factories has already been published.*

In calculating creamery dividends, the Babcock test is used to show the number of pounds of butter fat in the milk or the cream from which the butter is made. It shows the total fat in both cases. A certain amount of this fat, however, is returned to the milk patron in the skim milk, while all the gathered cream fat goes into the churn and only that left in the buttermilk is lost for butter making.

This skim milk fat amounts to about three per cent. of the whole milk fat, on the assumption that the skim milk tests about one-tenth per cent., and since the dividends are always calculated from the tests of the whole milk, the weights of fat of the cream patrons must be increased by three per cent. in order to give both milk and cream patrons their just share of the receipts. The cream patron probably does not know how much fat he left in the skim milk when his cream was separated, but in the creamery skim milk there is generally a nearly uniform loss which we have assumed to be three per cent. of the total fat in the milk. An illustration of the calculation of the dividends for milk patrons and cream patrons may help to explain the matter more fully.

Assuming that 125 pounds of butter are sold by a factory for thirty dollars, and that the factory receives four cents per pound for making the butter, which will amount to five dollars, this leaves twenty-five dollars to be paid to the patrons A, B, C, who supplied the following weights of milk and cream:

Patron.	Milk.	Test.	Butter fat.	Corrected weight.
	Lbs.		Lbs.	Lbs.
A	1,000	4.0	40	40.0
B	1,200	3.8	43.2	43.2
C	Cream. 100	16 3	16.3	16.8

The weight of butter fat from the cream patron should be increased by three per cent., and patron C who delivered

*Testing Milk and its Products, Sixth Edition, p. 160.

16.3 pounds butter fat, as cream should accordingly have this 16.3 multiplied by 1.03, which is equal to 16.8 pounds.

The weights of fat from which each patron's share of the receipts are calculated will be: A—40 pounds, B—43.2 pounds, C—16.8 pounds, or a total of 100 pounds fat, for which twenty-five dollars was received. From this we find that one pound of fat is worth twenty-five cents.

The amount due each patron is then found by multiplying his weight of fat by this price per pound, and in this case we would have the following:

A = 40 lbs. fat at 25 cts.	$10 00
B = 43.2 lbs. fat at 25 cts.	10 80
C = 16.8 lbs. fat at 25 cts.	4 20
	$25 00

In calculating the dividends of cream patrons when both milk and cream patrons come to one factory the weight of butter fat, found by testing the cream, is therefore multiplied by 1.03 and this result is taken as the total amount of fat delivered by the cream patron.

THE "COLUMBIA AIR CHURN."

E. H. FARRINGTON AND FRANK DEWHIRST.

Government records show that thousands of patents have been granted in this country for different kinds of churns. Every little while some "new idea" is advertised as an improvement over the common dash and barrel churns. The descriptive circulars generally claim that the "new idea" has solved all the difficulties every other churn has met with, and especially that with the new machine churning has been made easy.

When the subject of churns was under discussion last winter by the Short Course dairy class of this University, it was suggested that a student committee be appointed to purchase some patent churn and make a fair trial of its merits for the benefit of the whole class.

Claims are made for the Columbia Air churn that it has "completely revolutionized the old method of butter making," and the committee accordingly bought one of these churns from the Columbia Air Churn Co. of New York City. When received the churn was found to be a rather complicated piece of machinery as compared with the simple barrel churn. It consists of a wooden tub with flaring sides, standing on three legs about one foot from the floor. In the center of the tub is a vertical steel shaft resting in a wooden socket on the bottom and attached to the cover at the top. Around this shaft is an adjustable wooden tube, the lower part of which is shaped like a large inverted bowl. This wooden bowl tube can be raised or lowered as the churning progresses. There are two openings in the bottom bowl and one in the top of the cylinder around the shaft.

The descriptive circular of the manufacturers states that "the separation of the globules of butter fat from the cream is accom-

plished by a steady stream of air being forced down through a hollow wooden cylinder revolving at a high speed."

In operating the churn the openings in the bowl are submerged in the cream, while the opening at the top of the cylinder is above the cream. During churning the shaft and cylinder are revolved at a high speed by means of a bevel gear and crank attached to the churn cover and extending a foot or more above it.

This churn was placed by the side of a barrel churn of the same size and both were operated by a detail of students under conditions as nearly as possible alike, all of the work being carefully supervised by Mr. Dewhirst.

The printed instructions for operating the air churn were care fully followed, and when these called for the addition of water it was done, but the amount added was weighed, and the necessary corrections were in all cases made for this water when the buttermilk was tested. The churnings were made with ripened cream, containing from 20 to 30 per cent. butter fat, each lot of cream being equally divided between the two churns and both churnings carried on in the same room at the same time. The butter from each churn was washed, salted and worked uniformly and all possible care was taken to make a perfectly fair comparison of the two churnings. In all there were made forty-two churnings, twenty-one with each churn.

The details of each churning are given in Table I and a summary statement follows this table.

TABLE I.— *Results obtained with Columbia air churn and the barrel churn.*

Date.	Columbia Air Churn.						Barrel Churn.				
	Temperature of cream.	Cream fat, pounds.	Butter, pounds.	Per cent. overrun.	Buttermilk test.	Time required to churn, Min.	Cream fat. pounds.	Butter, pounds.	Per cent. overrun.	Buttermilk test.	Time required to churn, Min.
January 26	64	5.52	6.00	8.6	1.20	101	5.52	6.25	13.2	.21	31
January 29	60	4.08	4.50	10.3	.55	21	4.08	4.50	10.3	.10	20
January 30	52	5.64	6.50	15.0	.70	29	5.64	6.75	19.8	.13	32
January 31	50	7.20	7.70	7.6	.45	50	7.20	7.75	7.6	.06	43
February 1	55	4.72	5.25	11.2	.80	39	4.72	5.50	16.5	.23	37
February 2	57	5.76	6.25	8.5	.50	29	5.76	6.50	10.9	.10	29
February 3	53	5.28	5.25	......	.40	58	5.28	5.75	8.8	.14	50
February 5	60	6.36	7.00	10.0	.70	28	6.36	7.25	13.9	.10	32
February 6	59	7.87	8.25	4.7	.50	34	7.87	8.30	5.3	.13	40
February 7	58	5.64	6.00	6.2	.60	47	5.64	6.25	10.8	.13	30
February 10	60	6.52	6.75	1.9	.60	16	6.52	7.20	8.0	.12	25
February 12	60	6.12	6.25	2.1	.35	19	6.12	6.25	2.1	.07	25
February 13	60	6.75	6.75	......	1.50	12	6.75	7.13	5.6	.70	8
February 14	56	6.48	7.50	11.8	.90	17	6.48	7.75	19.5	.12	21
February 15	56	4.90	5.25	7.1	.75	14	4.90	5.50	12.2	.12	20
February 16	56	4.10	4.12	.5	.20	28	4.10	4.50	9.7	.08	26
February 17	55	5.00	5.50	10.0	1.00	17	5.00	5.75	15.0	.20	16
February 19	64	4.08	4.12	.9	1.80	11	4.08	4.25	4.1	1.00	10
February 20	64	5.75	6.00	4.3	.50	13	5.75	6.25	8.6	.40	19
February 21	64	6.75	7.75	14.8	1.80	17	6.75	8.00	18.5	1.20	15
February 24	52	6.87	7.50	9.1	.50	52	6.87	7.75	12.8	.05	60

TABLE II.— *Summary.*

	Number of churnings.	Cream fat, pounds.	Butter, pounds.	Per cent overrun.	Buttermilk test.	Temperature of cream.	Time required to churn, Min.
Air churn	21	121.39	130.19	7.25	.77	58	26.7
Barrel	21	121.39	135.13	11.31	.26	58	28.0

The following are some of the advantages claimed by the Columbia Air Churn Company in their circulars:

1. Quickness of churning: "An average churning does not take over five minutes."

2. Exhaustiveness of churning: "No matter how small the percentage of butter fat it gathers it all."

3. Greater butter production of higher quality: "We guarantee to increase the butter product in quality and quantity from 15% to 50% over that procured by any other method of churning."

5. Economy in cost: "Cheapest, considering what it will save and do for you."

Taking the results as noted in the table these claimed advantages may be examined in detail:

1st. *"Quickness of churning."* The average time required to churn in the air churn was 26.7 minutes, and in the barrel churn 28 minutes, a difference of 1.3 minutes in favor of the air churn.

2nd. *"Ease of Running."* The labor required to operate the air churn is very much greater than that needed by the barrel churn, especially with "heavy" cream, when considerable effort is necessary to turn the agitator of the churn. In one instance two men were required to hold the air churn steady while a third man turned the crank.

3d. *"Exhaustiveness of Churning."* The average test of the buttermilk from the air churn was .77% butter fat, from the barrel churn .26% fat. About three times as much fat was therefore left in the buttermilk from the air churn as in that from the barrel churn. In no instance was the buttermilk test so low in the air churn as in the barrel churn. The swelling of the cream and the subsequent shrinkage when the butter "broke" left some cream adhering to the sides of the churn. After the butter was removed the adhering cream was washed down with buttermilk and tested so as to determine the total loss in churning. No cream adhered to the sides of the barrel churn.

4th. *"Greater Butter Production of Higher Quality."* The yield of butter from 121.39 pounds of fat in the cream in the twenty-one churnings by the Air Churn was 130.19 pounds, making the "overrun" of butter over butter fat by the cream test equal to 7.25 per cent.

In the twenty-one churnings of the same amount of cream by

the barrel churn 135.13 pounds of butter was obtained, which is an increase of 11.31 per cent. This is a difference in favor of barrel churn of 4.06 per cent.

There was no noticeable difference in the quality of the butter from the two churns. The flavor was good for winter butter. The grain ranged from excellent at the lower churning temperature to poor at the higher one.

5th. *"Economy in Cost."* The cost of this six-gallon air churn was $12.00. This is $3.00 more than the same size of barrel churn costs.

The lasting qualities of the two churns are evidently quite different. The barrel churn is a small, revolving barrel with no extra parts to get out of order, and it is very easy to wash and to keep clean; with good care it will last a life time.

The Columbia Air Churn is composed of many parts, including a cog gearing, and a hollow wooden tube which requires careful attention to keep the wood from swelling and cracking. This complication of cogs and tubes is hard to clean and to keep in repair when one considers the speed at which the inside machinery revolves.

A RAPID METHOD FOR THE ESTIMATION OF SALT IN BUTTER.

ALFRED VIVIAN.

At the request of Mr. C. L. Fitch, superintendent of Hoard's creameries, Ft. Atkinson, Wis., an attempt was made, the past winter, to perfect a rapid method for the determination of the per cent. of salt in butter that would be sufficiently simple for use in the factory. It was apparent at the beginning that the official method of chemical analysis necessitating the use of a separatory funnel, burette and an accurately prepared standard solution, was too complicated for this purpose. Therefore, a series of experiments were first made to ascertain if it would not be possible to dispense with the use of the separatory funnel. The per cent. of salt was determined in seven different butters by the official method, using ten grams of butter, the washings from the separatory funnel being made up to 500 c. c. To another sample of each butter was added 510 c. c. of boiling water, the whole well shaken and allowed to stand until cool; it having been found by a previous experiment that it requires approximately 510 c. c. of boiling water to make 500 c. c. at room temperature. A portion of the liquid below the fat layer was drawn off with a pipette for titration. The following table gives the result of the salt determinations by both methods:

TABLE I.—*Per cent. of salt in butter by official method and by modification of the same.*

	1	2*	3	4*	5	6	7
Official method	3.00	2.58	2.50	5.35	1.13	3.15	3.05
Modified method	3.05	2.54	2.54	5.25	1.17	3.10	3 02

* Determinations made by Mr. Fitch under the direction of the writer.

It will be seen from the above table that the two methods agree so closely as to render the use of the separatory funnel unnecessary.

To obviate the necessity of using a burette it was decided to make the ...

... exceed one-tenth of one per cent. of salt, which would be of no consequence in ordinary determinations.

To overcome the difficulty of preparing the standard solution it occurred to the writer that tablets of silver nitrate might be made that would be sufficiently accurate for the purposes of this test. After some correspondence with Chas. S. Baker & Co. of Chicago, and several trials on their part, they succeeded in making a tablet that has proved very satisfactory. Tablets of the indicator (potassium chromate) were made but were unsatisfactory, as they failed to react properly after being kept a few weeks, so it was thought best to use a stock solution prepared from the pure salt. The method as originated required a 50 c. c. pipette. At the request of Mr. Fitch the size of the tablet, etc., was modified so as to permit of the use of a 17.6 c. c. pipette, the same as in the Babcock test.

How to use the test.—The standard silver nitrate solution is made by dissolving two of the tablets in 100 c. c. of pure water contained in a 100 c. c. graduated cylinder. This solution should be freshly prepared each time.

Make the indicator by dissolving one gram (or fifteen grains) of pure potassium chromate in one liter (or one quart) of water. This will keep indefinitely. Weigh out exactly 3.5 grams of butter on a piece of parchment paper such as is used in packing butter. Care must be taken to have the sample representative by taking small pieces from a number of places throughout the mass. The weighed sample (paper and all) is then placed in a flask or bottle of from 250 c. c. to 300 c. c. capacity, and 180 c. c. of boiling water added. The bottle is corked and thoroughly shaken. It will be necessary to proceed cautiously at first, removing the cork occasionally to relieve the pressure. The

mixture is then allowed to cool to approximately room temperature. The cooling may be hastened bv running cold water over the bottle, but agitation must be avoided as it is desired to have all the fat solidify in a layer at the top.

When cold, 17.6 c. c. (equals 0.35 grains of butter) of the nearly-clear liquid below the fat layer is measured into a white cup, and to it is added the same quantity of the potassium-chromate solution. The standard silver nitrate solution is now added one cubic centimeter at a time, until the reddish color first formed does not entirely disappear upon stirring. The number of cubic centimeters of the silver solution required, divided by ten, gives the per cent. of salt in the butter.

The following table gives the results of the determination of salt in seven samples of butter from the local market by the official method and by the method described in this article:

TABLE II.—*Per cent. of salt in different butters as determined by official method and tablet method.*

	1	2	3	4	5	6	7
Official method..................	3.10	2.95	3.23	2.14	2.47	2.50	3.00
Tablet method..................	3.2	3.0	3.3	2.2	2.4	2.7	3.0

It will be seen that with care the method is capable of giving results very close to those obtained by the official method. The principal source of error is in taking the sample, and great care must therefore be exercised to have the weighed portion a fair sample of the whole.

The tablets should be stored in glass containers and always kept in the dark. There is a question as to how long the tablets will keep even under these conditions, but no change can be detected in tablets that have been in the laboratory nearly four months.

Mr. Fitch has designed an apparatus for use in this test, consisting of a tall glass cylinder and a pair of small butter triers. The cylinder is graduated at 180 c. c. and the top is closed with a rubber stopper holding a brass cock to relieve pressure during the shaking; the idea being to fill the cylinder to the mark with

boiling water, fill the two triers with butter, drop them into the water and proceed as described above. Trials made in this laboratory indicate that it is difficult to obtain a sample of the correct weight in this manner. The arrangement with the cylinder is however very convenient.

The tablets might be used for the determination of salt in a number of substances, by bearing in mind that one cubic centimeter of the solution prepared as directed equals one-tenth of one per cent. of salt, when 0.35 grams of the substance is taken for titration.

The tablets now in use consist of 0.0509 grams of silver nitrate combined with sufficient potassium nitrate to make a tablet weighing five grains, a trace of gum acacia being used to bind the materials together.

INFLUENCE OF RENNET ON CHEESE RIPENING.

S. M. BABCOCK, H. L. RUSSELL AND A. VIVIAN.

INTRODUCTION.

The art of cheese-making is very closely bound up with the action of the soluble enzymes contained in rennet extract. The characteristic property which this extract possesses of curdling the casein of milk enables this food product to be made, and although it has been used for thousands of years, still its action in relation to cheese making is even now far from being understood. It should be said that our knowledge of the action of rennet in milk itself has been fairly well developed through the labors of Hammersten and his followers, but the relation of this ferment to cheese ripening has hitherto received practically no attention. Nevertheless among cheese operators, notions have gradually grown up which have been considered as explanatory of the action of this agent. These hypotheses however do not rest upon an experimental basis, and as a class, they serve to show how little the art of cheese making, as practiced to-day, rests upon a broad scientific knowledge of the processes involved. The mere fact that these notions are so antagonistic shows that they have been based on crude conjectures rather than careful observations.

This is evident from the following quotations from noted dairy authorities:

"The author does not regard it as probable that in the ripening of rennet cheese, the rennet used to coagulate the milk exerts any subsequent influence."—(Fleischmann[1].)

[1] Book of the Dairy, p. 338.

"One of the functions of rennet is to render the casein soluble by coverting it into cheese."—(Arnold.[1])

"It was formerly supposed that the amount of rennet added had an effect on the whole process of manufacture and particularly upon the curing fermentation, but while the matter is still unsettled, later researches go to show that the influence of rennet upon the curing is probably very slight."—(Wing.[2])

"It is now admitted that rennet has nothing to do with the curing of cheese. The French and German investigators, to whom we are indebted for almost all our knowledge on this subject, do not recognize rennet as a curing agent at all, but attribute the changes which occur during the ripening process to the action of bacteria."—(Ruddick.[3])

Van Slyke[4] gives results of chemical examinations of cheese made with varying quantities of rennet in which he found an increase of soluble products with an increase of rennet.

In view of the marked discrepancy in this field, not only as to the conclusions drawn, but even in regard to the facts themselves, it became necessary for us to start our investigations from the very foundation. The problem was then, to determine what influence varying quantities of rennet have on the rate of ripening, when measured by chemical as well as physical standards; but before taking up this problem, a brief summary of the nature of rennet may be of service in this connection.

NATURE OF RENNET.

The active principle in rennet extract comes from the soluble ferments (enzymes) found in the intestinal tract, especially in the stomachs of suckling animals. Naturally such an extract is far from being a pure solution of any one substance, but contains all of the material soluble in the menstruum used. While the active principle is the coagulating ferment, *rennin,* which has the power of coagulating the casein of milk, rennet extracts always contain more or less of the enzyme *pepsin* which exerts

[1] American Dairying, p. 294.

[2] Milk and its Products, p. 174.

[3] Ontario Dairymen and Creameries' Assn., Rept. 1896, p. 22.

[4] 12 Rept. N. Y. Expt. Station, p. 277.

a digestive effect upon casein, in slightly acid solutions. This fact must be borne in mind, in considering the action of rennet extract; for we are here dealing not with a known solution of one substance but with a mixture of at least two ferments.

EXPERIMENTS WITH DIFFERENT QUANTITIES OF RENNET EXTRACT.

To determine the influence that various quantities of rennet exert upon the rate of ripening in cheddar cheese, a number of cheese were made in which different quantities of rennet were added to equal weights of milk. These cheese were made and kept under uniform conditions, the amount of soluble proteids being determined at stated intervals by the method previously described.[1] These results are incorporated in Table I.

TABLE I.—*Influence of different quantities of rennet on the digestion of cheese.*

Quantity of rennet added per 1,000 lbs. milk.	Per cent. of soluble nitrogen in cheese.			
(Ozs.)	Initial.	32 days old.	85 days old.	270 days old.
2	.14	.47	.68	1.30
4	.16	.75	1.13	1.74
8	.16	.90	1.50	1.97
16	.14	1.26	1.71	2.04

An increase in the amount of rennet used is always accompanied, in this case, by an increase in the amount of soluble nitrogenous products.

That this increase is due to the activity of the ferment added, and not to the soluble products contained in the extracts used is shown by the initial nitrogen being practically the same in all cases. This increased digestive action has been confirmed in several other series, the details of which it is not necessary to give in this connection, as they will be more fully discussed subsequently. Van Slyke has previously presented data that show the same effect, as indicated in Table II.

[1] 16 Rept. Wis. Expt. Station, 1899, p. 179.

TABLE II.—*Influence of rennet extract upon digestion of cheese (compiled from Van Slyke).*

Amount of rennet used.	Per cent. of total nitrogen in form of albumen and soluble casein.[1]	
(Ozs.)	Green cheese.	Cheese 5 months old.
3	0.13	1.52
9	0.12	1.92

[1] In Van Slyke's work, the albumen is included in the digestion products, whereas in our work the soluble nitrogen does not include this group.

These results indicate that the rate of ripening is a function of the amount of rennet used—that an increase in rennet above the normal amount causes the cheese to ripen more rapidly. But what causes this increased rate of change? An answer to this question would be equivalent to an explanation of the phenomenon of rennet action, a problem which has yet received no satisfactory answer from either the scientific or practical points of view.

THEORIES EXPLANATORY OF RENNET ACTION.

Mere reference only need be made to the views propounded by Hallier[2] that the action of rennet is attributable to the activity of living ferments, the fungi and bacteria present in solutions of rennet.

The two modern views that are generally advanced as explanatory of this action by those who consider that rennet has any effect are:

1. That an increase in the amount of rennet tends to increase the moisture of cheese and so hasten the ripening process.

2. That the increase in rate of digestion where large quantities of rennet are used may be attributable to the presence of digestive ferments in such extracts.

INFLUENCE OF RENNET ON MOISTURE OF CHEESE.

The first hypothesis is held by Robertson,[3] who says: "The more rennet there is used the more moisture there will be re-

[2] Martiny, Die Milch, p. 89.

[3] 16 Rept. Wis. Dairymen's Assn., p. 204.

tained in the cheese under similar conditions of making * * * * * * The more moisture there is retained the more quickly it will cure under equal conditions of temperature and moisture."

The evident inference from this is that the addition of rennet increases the moisture in the green cheese and so hastens the ripening process.

To obtain experimental data regarding the influence of varying amounts of rennet upon the moisture content of cheese, the following experiments were made under our direction by Mr. John Michels, in which varying quantities of rennet were added to milks of the same character, and cheese made therefrom. The percentage of moisture noted represents the water content when taken from the press:

TABLE III.—*Influence of varying quantities of rennet on the moisture content of cheese.*

PER CENT. BUTTER FAT.	NO. OF OUNCES OF RENNET PER 1,000 POUNDS OF MILK.					
	3	6	9	12	18	24
	Per cent.	Per cent	Per cent.	Per cent.	Per cent.	Per cent.
4.1	34.44	....	34.17	....	....	....
4.3	34.77	33.67	33.31	....	....	....
4.3	34.73	....	....	34.41	....	34.47
4.5	36.57	35.15	35.36	....	....	....
4.7	35.15	....	34.66	....	34.16	....

The above table shows that the cheese made with the larger quantities of rennet do not contain more moisture than those made with the normal amount; but on the other hand are even drier. Of the cheese made with three and nine ounces of rennet, from milks containing the same per cent. of fat, the average moisture content of the three ounce group was 35.23%, while the nine ounce group contained only 34.37%.

From these experiments it does not seem probable that the hypothesis advanced regarding the increased moisture of high rennet cheese is tenable.

DIGESTIVE FERMENTS IN RENNET.

The earlier representatives of those who held that rennet possessed a digestive action erroneously ascribed this effect to the proteolytic action of the curdling principle itself. Subsequent studies have shown, as previously noted, that rennet extract contains at least two separate ferments, viz., rennin, the coagulating enzyme, and pepsin, the digestive ferment of the stomach. Admitting that an increase in rennet does hasten the rate of digestion, is it not possible that this proteolytic action may be due to the pepsin contained in such extracts?

It is a well known fact that it is possible to differentiate in part between the action of rennin and pepsin by means of heat. The activity of rennin is greatly impaired by the application of heat in other than absolutely neutral solutions, while pepsin can withstand a high temperature much better, especially in a slightly acid solution, although even then its action is somewhat weakened. It might therefore be possible to inhibit the coagulating principle of rennet extract without wholly destroying its proteolytic activity. The following experiment permits of a comparison of the action of unheated rennet extracts, and extracts heated to 152° F. for five minutes. This temperature does not entirely destroy the coagulating ferment, but it weakens its action to a very large extent. It was necessary to retain some rennet action in order that a cheese might be made. In these experiments the retardation of the curdling action of the heated rennet is also shown:

TABLE IV.—*Influence of heated rennet extracts on formation of soluble proteids in cheese.*

Amount of rennet used per 1,000 lbs. milk.	Time of coagulation.	PER CENT. SOLUBLE NITROGEN.		
		32 days.	85 days.	270 days.
	(Seconds.)			
16 ounces of unheated rennet	125	1.26	1.71	2.04
16 ounces of heated rennet	390	.88	1.22	1.70
32 ounces of heated rennet	180	1.14	1.57	2.04

This table indicates conclusively that the application of heat to the rennet extracts seriously interferes with their coagulating power, but at the same time, it must be noted that their proteolytic action is also greatly decreased. This experiment therefore does not permit of a definite conclusion being drawn, as to the cause of increased digestion where large amounts of rennet are used.

STUDY OF SOLUBLE DECOMPOSITION PRODUCTS IN HIGH RENNET CHEESE.

Previous studies have shown that the soluble nitrogenous products formed during the ripening of cheese are uniform in character and subject to definite determination, and that they agree in all particulars with the decomposition products formed by galactase in sterile milks.[1] It seemed advisable therefore to study the nature of these products in cheese made with varying quantities of rennet, to determine whether there was any demonstrable difference that could be detected by this method of chemical examination.

Series I.

Table V gives the amount and nature of the various decomposition products found after 270 days in typical cheddar cheese made with 2, 4, 8 and 16 ounces of rennet per 1,000 pounds of milk, and also with 16 and 32 ounces of rennet which had previously been heated to 152° F. for five minutes.

TABLE V.—*Influence of amount of rennet extract upon formation of decomposition products in cheddar cheese (270 days old).*

Ounces rennet used per 1,000 lbs. milk.	Total nitrogen	Total soluble nitrogen.	Per Cent. of Nitrogen as					
			Insoluble.	Albumoses.	Peptones precipitated by		Amides.	Ammonia.
					Tannin.	Phosphotungstic acid.		
2........	4.48	1.30	3.18	.06	.16	.13	.87	.08
4........	4.55	1.74	2.81	.13	.25	.26	.96	.14
8........	4.34	1.97	2.37	.29	.26	.20	1.06	.16
16........	4.63	2.04	2.59	.34	.25	.19	1.12	.14
16 heated	4.55	1.70	2.85	.22	.36	.14	.88	.10
32 heated	4.70	2.04	2.66	.18	.51	.15	1.05	.15

[1] 16 Rept. Wis. Expt. Station. 1899. p. 157.

This data is also shown in graphical form in following diagram:

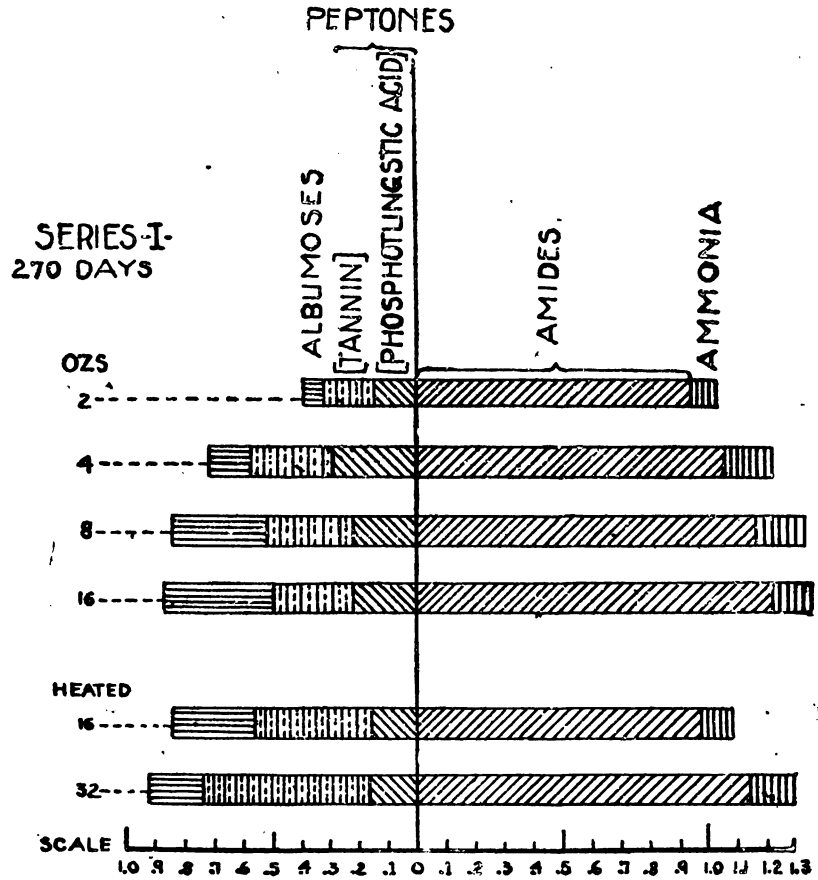


FIG. 12.—Amounts of proteid decomposition products found in Cheddar cheese made with varying quantities of rennet extract, raw and heated, after 270 days. The heavy line through all groups separates the higher from the lower decomposition products.

From this data it is apparent that all the various decomposition groups of nitrogenous bodies are represented in all cases; that with an increase in amount of rennet used, the total soluble nitrogen is increased, and that this increase in this case is quite well distributed among the different groups.

As the different decomposition products formed in the cheese made in Series I were not determined until the cheese were nine months old, it was thought best to repeat this work, making

analyses at stated and earlier intervals, in order to test the validity of the results previously obtained.

Series II.

Accordingly cheese were made with 3, 9 and 18 ounces of rennet per 1,000 pounds of milk, and the soluble nitrogenous products differentiated at the age of one, two and six months with the following results:

TABLE VI.—*Amount of different nitrogenous decomposition products formed at different stages of ripening in cheese made with varying quantities of rennet.*

	Total nitrogen.	Total soluble nitrogen.	Per Cent. of Nitrogen as					
			Insoluble.	Albumoses.	Peptones precipitated by		Amides	Ammonia
					Tannin	Phosphotungstic acid.		
One month old:								
3 oz. of rennet..	4.20	.65	3.55	.26	.15	.09	.15	Tr.
9 oz. of rennet..	4.25	.84	3.41	.45	.15	.09	.15	Tr.
18 oz. of rennet..	4.18	.99	3.19	.60	.15	.09	.15	Tr.
Two months old:								
3 oz. of rennet.	4.50	.90	3.60	.14	.24	.10	.40	.02
9 oz. of rennet..	4.45	1.09	3.36	.25	.32	.10	.40	.02
18 oz. of rennet..	4.50	1.26	3.24	.33	.41	.10	.40	.02
Six months old:								
3 oz. of rennet..	4.60	1.36	3.24	.20	.21	.08	.70	.17
9 oz. of rennet..	4.55	1.60	2.95	.42	.25	.08	.69	.16
18 oz. of rennet..	4.55	1.88	2.67	.68	.27	.07	.70	.16

While there is a constant increase in the amount of total soluble nitrogen where there was an increase in amount of rennet used, which increase persists for the different age-periods at which the cheese were analyzed, yet the important observation should be noted that in this series, the increase is confined to the higher and more complex proteid decomposition-products, including the albumoses and the peptones precipitated by tannin. For the different ages at which the cheese were examined, the amount of nitrogen in the form of the lower decomposition products, (peptones precipitated by phosphotungstic

acid, amides and ammonia) is the same regardless of the amount of rennet used.

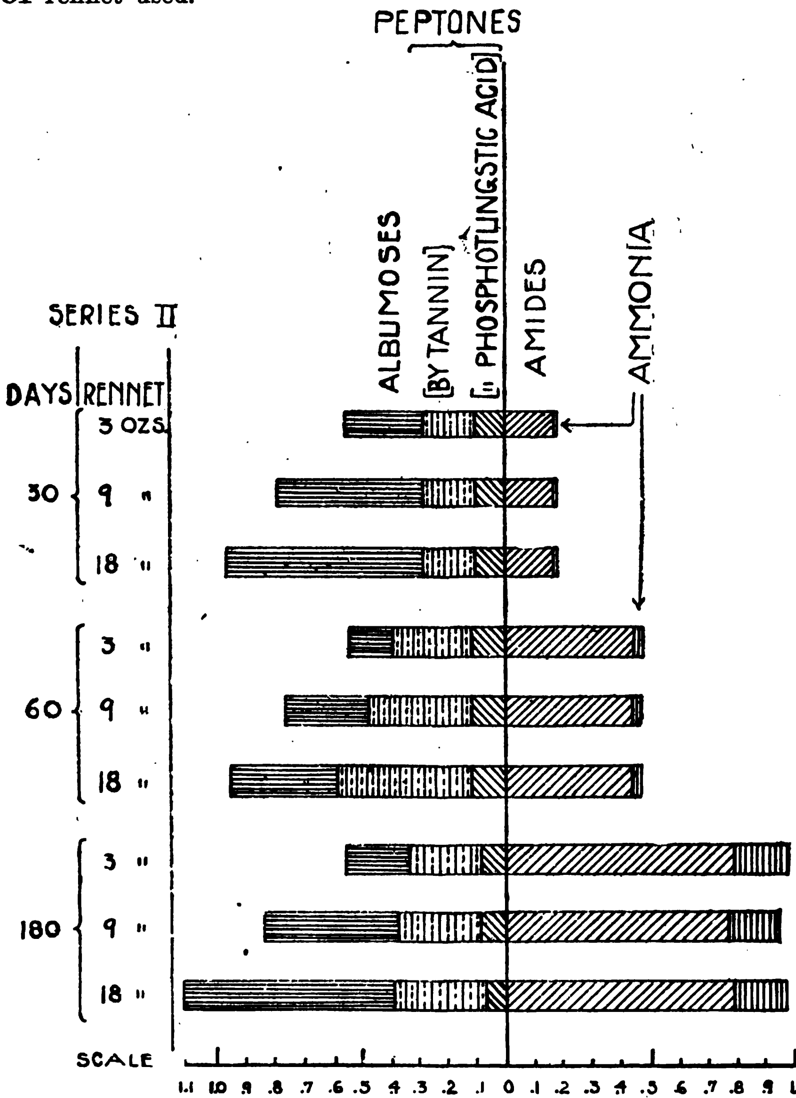


FIG. 13.—Proteid decomposition products found in cheddar cheese, made with varying amounts of rennet and analyzed at successive intervals. The increase in soluble products is confined to the higher decomposition groups shown at the left of the heavy vertical line.

Inasmuch as these lower groups are the distinctive by-products of galactase decomposition on the casein of milk,[1] it seems more than probable that this portion of the digestion of the casein

[1] 16 Rept. Wis. Expt. Station, 1899, p. 170.

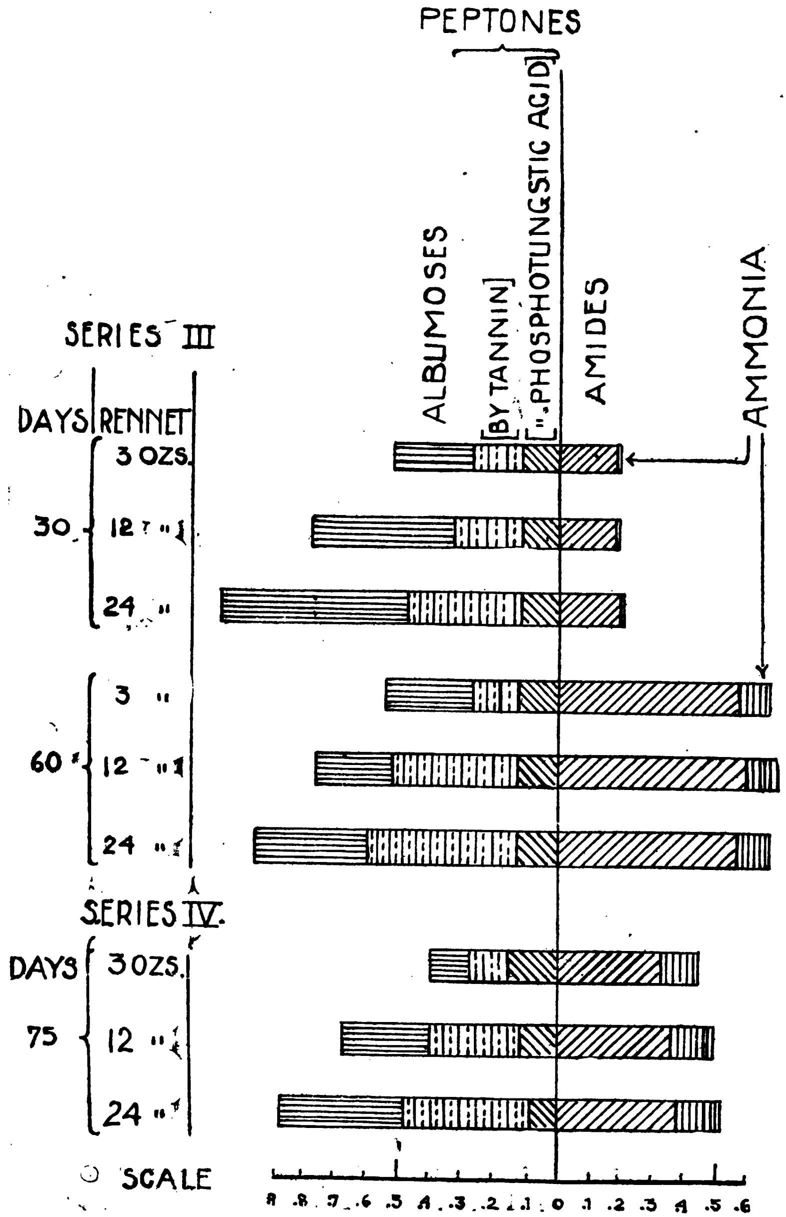


FIG. 15.—Proteid decomposition products in cheddar cheese made with varying quantities of rennet extract at different stages of ripening. These series confirm the results obtained in Series II.

Series IV.

This series consists of a set of cheese made independently by Mr. John Michels and also analyzed by him. They were made from ordinary factory milk, using the same amounts of rennet as in Series III. The differential analysis was made when the cheese were 72 days old. The results obtained are presented in table VII.

In order that a comparison of the results obtained in Series III and IV may be made with the diagram given under Series II, Fig. 15 is presented.

The conclusion that is evident from Series III and IV confirms exactly that noted in Series II, i. e., the increase in soluble nitrogenous products where an increased amount of rennet was used, is confined for each period to those decomposition products precipitated by tannin, the sum of the lower products being practically the same for each amount of extract used.

These concordant results indicate conclusively that the increased digestion of cheddar cheese made with large amounts of rennet is due to the pepsin which the extract contains.

ACTION OF INCREASED AMOUNTS OF PEPSIN IN RENNET EXTRACT USED IN CHEESE MAKING.

If increased digestion of cheese made with large quantities of rennet is due to the action of the pepsin contained in such extract, then the crucial test of this hypothesis would be to add pure pepsin to ordinary rennet extract and determine if increased digestion follows; for, the action of pepsin should be the same whether it was originally present in the rennet solutions or had been freed from other impurities. According to this hypothesis cheese made with rennet to which pepsin had been added should not only contain an increased amount of soluble nitrogenous products, but the increase in soluble nitrogen should be confined to those products that are characteristic of peptic digestion; i. e., albumoses and the higher peptones.

To test the hypothesis the following series of experiments were performed. Cheese were made as follows:

1. Ordinary cheese made from 125 pounds of milk with 10 c. c. of commercial rennet extract.

2. Same as 1, with the addition of 4 gms. Parke, Davis & Co.'s aseptic pepsin.

3. Same as 2, but pepsin solution was first acidified[1] to 0.2% HCl.

4. Same as 1, with 4 gms. German scale pepsin.

5. Same as 4, but pepsin first acidulated as in 3.

6. Same as 1, with 4 gms. Armour's pepsin.

7. Four gms. Armour's pepsin with *no rennet extract.*

8. Four gms. Parke, Davis & Co.'s pepsin with *no rennet extract.*

After 21, and also after 70 days, the soluble nitrogen in each of these cheese was determined with the following results:

TABLE VIII.—*Influence of pepsin on digestion of cheese.*

DATE OF MAKING.	Age when analyzed	PER CENT. OF TOTAL SOLUBLE NITROGEN.							
		Cheese No. 1.	Cheese No. 2.	Cheese No. 3.	Cheese No. 4.	Cheese No. 5.	Cheese No. 6.	Cheese No. 7.	Cheese No. 8.
	Days.								
June 27........	21	.73	1.18	1.18	....	....	....	....	....
June 28........	21	.71	1.11	1.10	....	....	....	....	....
June 29........	21	.73	....	....	.88	.94	1.26	....	....
July 2........	21	.73	....	....	....	....	....	.99	1.01
June 27........	70	1.08	1.48	1.47	....	....	....	....	....
June 28........	70	1.02	1.40	1.42	....	....	....	....	....
June 29........	70	1.21	....	....	1.26	1.40	1.68	....	....
July 2	70	1.28	....	....	....	....	....	1.44	1.50

The influence of pepsin on the digestion of cheddar cheese is evident from this, there being no exception to the rule that the increase in soluble nitrogen was in excess of any of the checks which were made with rennet extract alone. Considerable variation in pepsin digestion is, however, to be noted when the different brands of pepsin are compared. The diminution in peptic action of the German scale pepsin was undoubtedly due to the fact that this sample was several years old. In this case, acidulation of solution aided somewhat in digestion, but in the case of the fresh samples no increase of this sort was observed.

[1] Nos. 3 and 5 were acidulated because previous experience with some pepsins had indicated that the activity of the enzyme was in this way intensified.

SIMILARITY IN ACTION OF PEPSIN AND RENNET EXTRACT IN CHEESE.

While the soluble nitrogen in the foregoing series was invariably greater in those cheese to which pepsin had been added to the rennet extracts used, this conclusion can be further strengthened by comparing the character of the decomposition products formed in high rennet and pepsin cheese. It has already been shown in the high rennet cheese (p. 110) that the increase in soluble nitrogen is confined to the higher peptones and albumoses. A differential analysis of the normal and pepsin cheese made on June 27, as shown in Table IX, indicates that the same conclusion holds with reference to the cheese made with the addition of pepsin. The identity of the by-products of the pepsin and high rennet cheese is thus established.

TABLE IX.—*Amount of nitrogenous decomposition products produced in high rennet and pepsin cheese in comparison with normal rennet cheese.*

(Age when analyzed 70 days.)

	Total nitrogen.	Total soluble nitrogen.	Insoluble.	Albumoses.	Peptones precipitated by Tannin.	Peptones precipitated by Phosphotungs acid.	Amides	Ammonia.
Normal cheese (No. 1).............	4.05	1.08	2.97	.23	.21	.11	.49	.04
Normal cheese, + pepsin (No. 3).....	3.95	1.48	2.72	.54	.30	.11	.49	.04

INFLUENCE OF ACIDITY OF CURD ON RATE OF PEPTIC DIGESTION.

In the series of pepsin cheese (page 115) the milks were generally well ripened, although they were not carried further than was compatible with good cheddar treatment. In the previous year a series of experiments on pepsin cheese, made under our direction with the old German pepsin by Mr. John Michels, showed no increased digestion, but in these cases the milk was not ripened down, neither were the curds ched-

dared so far on the rack. It is probable that the acidity in these cases were not sufficient to promote the activity of this sample of old pepsin. This view is strengthened by the fact that in the cheese made on June 29, this same pepsin was used, and in these cheese which were well cheddared, the digestive action was markedly apparent, although even this was intensified when the pepsin solution was first acidified.

This point suggests the possibility that the action of pepsin in rennet extract is closely related to the extent to which the cheddaring process is carried, that the more acid there is developed in the curd, the more marked is the influence of the pepsin in the curing of cheese. This view is still further substantiated by the data presented in Table X.

If cheese 7 and 8, made with Armour's and Parke, Davis & Co.'s pepsin, respectively, are compared, it is seen that the digestion is practically the same, showing that their activity under similar conditions is nearly identical. But in the highly cheddared cheese, No. 6, made with Armour's pepsin, the digestion was considerably more than in No. 3 cheese (June 27 and 28) made with Parke, Davis & Co.'s pepsin. In this comparison the otherwise equally active pepsins show a marked difference, which can best be explained by the difference in acidity. Still further confirmation of this view is shown in a series of experiments which were made to determine the acidity in milk necessary to cause digestion where rennet extract is added to the same.

In our work of the previous year[1] it had been observed that the addition of rennet extract or even purified pepsin to fresh milk failed to produce any increase in soluble nitrogenous products, but when 0.2% HCl was added, digestion proceeded in each case, the increase being confined exclusively to the albumoses. To determine the degree of acidity necessary to facilitate peptic digestion in milk, an experiment was made as follows:

To milks in which the galactase had been destroyed by heat, different amounts of lactic acid were added, varying from .05–.3%, the original milk having an acidity of .13%. To these

[1] 16 Rept. Wis. Expt. Station, 1899, p. 171.

samples, commercial rennet extract was added in proportion of 1 :100, and after 100 days incubation at 35° C., the soluble nitrogen was determined as is shown in Table X.

TABLE X.—*Influence of acidity on digestion of milk by renne extracts.*

Original acidity of milk (determined with phenolphthalein as indicator)							13 per cent.
Lactic acid added (per cent.)	...	.05	.10	.15	.20	.25	.30 per cent.
Total acidity in per cent	.13	.18	.23	.28	.33	.38	.43 per cent.
Soluble nitrogen after 10 days	.06	.06	.06	.06	.08	.09	.11

Expresed graphically, as in fig. 16, the relation of acidity to peptic action is more manifest.

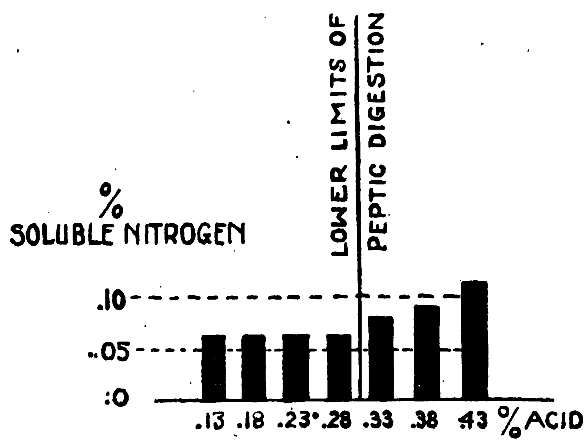


FIG. 16.—Diagram showing degree of acidity necessary to cause peptic digestion in milk.

These results show that the conditions in milk do not favor the digestion of the casein as produced by the peptic ferments of rennet extract until the acidity of the milk approximates 0.3% lactic acid. This point conforms closely to the limit set by cheddar practice.

A previous experiment made where lactic acid alone was added to boiled milk showed no increase in soluble nitrogen, thus indicating that the lactic acid by itself has no digestive action on casein in the proportions in which it would exist in milk or cheese.

In order to compare the activity of different brands of pepsin used in these experiments the following tests were made.

To sterile galactase-free milk, pepsins of different origin were added in proportion of 1:400. Each lot was divided and one portion acidified by adding 0.2% HCl. To these chloroform was added.

TABLE XI.— *Comparative activity of different pepsins in milk of different acidities.*

	Per Cent. of Soluble N. After 14 Days.	
	Fresh milk.	Acidified.
Control milk	.08	.08
Armour's pepsin	.08	.32
Parke, Davis & Co.'s pepsin	.08	.33
German scale pepsin (old)	.06	.18

While free acids (HCl or lactic) were added in all of these experiments to the milk, still acidity tests of the same with Congo red as indicator have never shown any free acid present. This would indicate that the free acid added had combined with the phosphates or perhaps with the casein, thus forming acid salts. It is generally supposed that pepsin requires free acid for its action, but in milk at least acid salts appear to replace this condition.

This point was tested directly by acidifying milk with cream of tartar (potassium acid tartrate) instead of free lactic or mineral acids. Sufficient amount of this acid salt was added to milk to produce an acidity (with phenolphthalein) equivalent to 0.45% lactic acid; and to portions of this milk, Parke, Davis & Co's. pepsin (1:400) and rennet extract (1:100) were respectively added. Analyses after two weeks incubation at 35° C. showed following results:

Control milk	.04 per cent. soluble N.
Pepsin (1:400)	.28 per cent. soluble N.
Rennet extract (1:100)	.18 per cent. soluble N.

The view previously advanced that acid salts can replace free acid in peptic digestion is thus confirmed.

GENERAL SUMMARY.

Notwithstanding the fact that rennet has been used in the manufacture of cheese since the dawn of history, yet its action, especially as regards its effect on the ripening of cheese, has never been satisfactorily explained. It is even yet a disputed question as to whether it has any effect except to coagulate the milk.

The views of those who adhere to the notion that it is also concerned in the ripening of cheese are at variance with each other, and but rarely have been at all supported by scientifically controlled experiments.

The claim has been advanced that rennet incorporates more moisture in the cheese and thus indirectly hastens the ripening process. The other view that has been held attributes its effect to the direct action of digestive enzymes that are normally present in rennet extracts. This view has had no experimental basis but has obtained credence simply because rennet extract being derived from the stomachs of young animals would be likely to contain digestive (pepsin) as well as coagulative (rennin) enzymes.

The conclusions drawn from the experiments herein detailed are as follows:

1. That an increase in amount of rennet extract used *does increase* the amount of soluble nitrogenous products, which measure the progress of cheese ripening.

2. Increase in amount of rennet used does *not* increase the water content of cheese, and therefore, the ripening of cheese can not be indirectly affected in this way.

3. The products of peptic digestion in milk and cheese are confined to the higher decomposition products, viz., albumoses and peptones precipitated by tannin.

4. The increase in soluble nitrogenous products in cheese and also in milk due to an increase in amount of rennet extract used are also confined to those by-products that are peculiar to pepsin, thus indicating that the digestive action of rennet extract is attributable to the action of the pepsin incorporated with the rennet extract.

5. The crucial test of this conclusion was made by adding purified pepsin to milk and making the same into cheese, where rennet extract was or was not added to curdle the milk. In such cheese digestion has been increased in those cases to which pepsin has been added, and this increase has been confined to those by-products that are characteristic of pepsin, and which also appear in cheese made with high quantities of rennet.

6. The digestion in cheese incident to pepsin is determined mainly by the degree of acidity developed in the milk and curd. In cheddar cheese, peptic digestion probably does not begin until the acidity of the milk is approximately 0.3% lactic acid.

7. Acid salts as phosphates, etc., favor peptic digestion in milk in a manner comparable to free acids.

8. Free acid does not normally exist in cheddar cheese, the apparent acidity being due to acid salts.

Summarizing these conclusions, rennet exerts a digestive effect on the casein of cheese due to the presence of peptic enzymes contained in rennet extracts, the action of which is intensified by development of acid in the curd. The soluble nitrogenous products formed in cheddar cheese by rennet are the albumoses and the higher peptones that are precipitated by tannin.

SUPPLEMENTARY NOTE.

After the completion of this article, we received from Orla Jensen, of Berne, Switzerland, a separate from the Landwirtschaftliches Jahrbuch der Schweiz for 1900 on "Studien über die Enzyme in Käse" in which is detailed a series of experiments from which is derived the same conclusions regarding the influence of acidity on the peptic digestion of rennet in cheese that have been drawn in the foregoing article, (p. 119). Jensen found that the soluble nitrogenous products of cheese made with the addition of lactic acid were increased, and that this increase was confined to the products peculiar to pepsin. As he arrived at his results by a method radically different from the one used in this work, the conclusions thus independently obtained as to the influence of the pepsin in rennet extract on cheese digestion are very materially strengthened.

CAUSES OPERATIVE IN THE PRODUCTION OF SILAGE.

S. M. BABCOCK AND H. L. RUSSELL.

The preservation of forage plants in silos is a question of such economic importance in agriculture that a thorough understanding of the causes operative in the production of such material is desirable. When green plants are cut and placed in a heap, certain physical and chemical changes occur; the mass undergoes a rapid evolution of heat, and in a short time a marked chemical decomposition is to be observed. These changes take place when the material is stored in closely compacted stacks, in pits in the ground, or in air-tight receptacles. They are accompanied by a loss of dry matter which is greatly increased by access of air, and various organic acids are formed which give the silage a more or less sour taste. In practice these losses are subject to much variation, ranging from three to forty per cent, depending upon the completeness with which air is excluded. In perfectly tight silos the losses are reduced to a minimum. Where the construction of the silo is such as to permit of leakage of air, molds and other ferments develop rapidly, resulting in largely increased losses. The losses may therefore be divided into (1) those which are unavoidable even in air tight silos, and (2) those incident to faulty construction of silo.

It is the purpose of this paper to consider mainly the causes that are operative in these changes which occur in the formation of good silage.

While the word *silage* is generally applied to all kinds of green fodders that are preserved in stacks, pits or silos where atmospheric air is more or less excluded, still there is a great deal of difference in the physical, chemical and nutritive properties of such preserved fodders as they occur in actual practice. It

is therefore necessary, at the outset, to limit the interpretation applied in this connection to the word *silage*. By this term, in this discussion, is meant preserved fodders that have acquired an aromatic odor and slightly acid taste, without the development of putrefactive or moldy flavors or odors. It frequently happens that some ensiled fodders acquire an excessively acid taste, while in appearance they resemble the more normal silage. Such fodders are most often produced when the tissues are ensiled in too immature a stage, and may be designated as sour silage in contradistinction to sweet silage, a term often applied to the more normal product.

PHENOMENA INCIDENT TO SILAGE FORMATION.

When green fodders are ensiled in ordinary silos, the most obvious phenomena connected with this process are the rise in temperature of ensiled material, change in color, and development of more or less acid taste, accompanied with the production of an aromatic odor. There is also a considerable evolution of gas which of course is not evident to the casual observer, but inasmuch as it always occurs at the time that the fodders are ensiled it may be considered as an accessory phenomenon. As the heating of ensiled fodders is the most obvious change, this phase of the subject will be given first consideration.

CAUSE OF INITIAL HEATING.

All recent work on the matter of silage changes and more especially the rise in temperature observed immediately after the fodder is ensiled seems to have ascribed the production of heat to the action of bacteria, more especially to the thermophilic or heat-tolerating forms.

The above view, expressed by a considerable number of different writers[1] represents the current trend of thought relating to the cause of the initial heating. Nearly two decades ago, Fry[2] advanced the view that this heating was due to the respiration

[1] Burrill, Bull. 7, Ill. Expt. Station; Griffiths, Chem. News, Vol. 70, No. 1,828; Lafar, Technical Mycology, p. 262; Conn, Story of Germ Life, p. 113.

[2] Fry, Theory and Practice of Sweet Ensilage, p. 17.

of the cut vegetable tissues, but his ideas did not meet with acceptance and have since that time been entirely neglected in the prevailing tendency to explain all fermentative effects as due to microbic action.

EFFECT OF DIRECT RESPIRATION ON HEAT PRODUCTION.

That large quantities of heat are evolved as a result of the direct oxidation of organic matter by the respiration of living tissues is a most fundamental physiological law, and one which is unquestionably operative in this connection; for the most marked production of heat is noted in the upper layers of the silage that are directly exposed to the air. It is possible to distinguish between the heat produced by direct respiration and

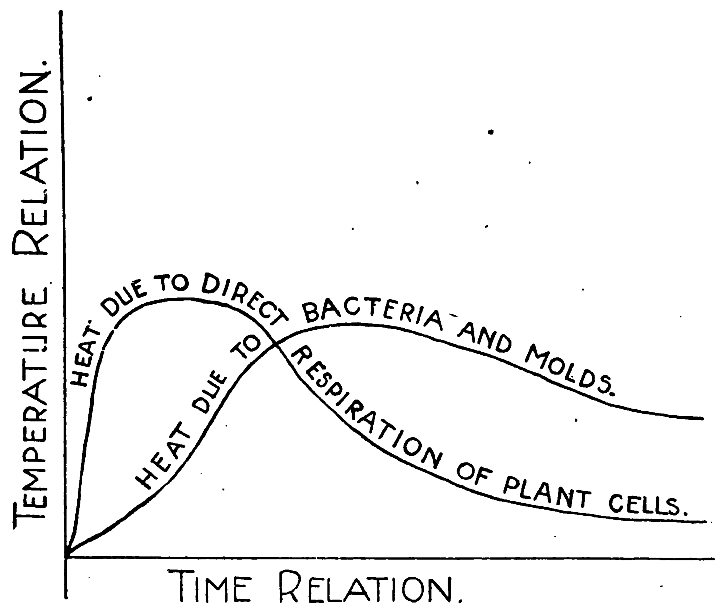


FIG. 17.—Diagram showing respiration activity of plant tissues and extracellular ferments (bacteria and molds) as measured by heat evolved.
Maximum temperature caused by direct respiration of plant tissues is attained more quickly than with bacteria, because of the necessary period of incubat'on of the latter.

that due to bacterial growth by the rate of production. Heat due to direct respiration of the plant cells reaches its maximum earlier because the cells producing the same are already active, while if due to bacterial and mold development, this is delayed,

because of the necessary period of incubation that must elapse before the bacteria increase sufficiently to be able to cause any appreciable heat, a condition which would be represented theoretically as in fig. 17.

The following data show the temperature range of a small mass of cut corn exposed to the air under conditions favorable to direct respiration.

TABLE I.— *Temperature of cut corn exposed to air.*

		° F.
Temperature of corn	3 P. M., Sept. 17,	66
Corn in open retainer, surface exposed to air	11 A. M., Sept. 18,	101
	3 P. M., Sept. 18,	106
	5 P. M., Sept. 18,	110
Evidence of mold and bacterial development	8 A. M., Sept. 19,	110
	8 A. M., Sept. 20,	102
	5 A. M., Sept. 20,	100
	8 A. M., Sept. 21,	95

In this experiment, radiation was rapid as the corn was not insulated, still within twenty-four hours from the time of cutting, it reached the maximum temperature, and this occurred before there was any visible evidence of bacterial or mold action.

EFFECT OF WOUNDING TISSUES ON HEAT PRODUCTION.

Pfeffer,[1] Boehm,[2] and Richards[3] have previously shown that the direct respiration of vegetable tissues is affected by wounding, that there is an increase in the amount of heat evolved under such conditions, and that this increase reaches its maximum within one or two days. This condition applies to silage as fodder is usually cut before ensiling.

The following experiment as to the heat produced by the direct respiration of corn cut in small pieces one inch long, and in sections two feet in length show the influence of this traumatic stimulus.

[1] Jahr. Ag. Chem., 1896, p. 254.

[2] Bot. Cent., 1892, 50:20.

[3] Ann. Bot., 10:531, also 11:31.

TABLE II.—*Heat evolved by the direct respiration of corn cut in long and short pieces.*

DATE.	CORN CUT IN PIECES.	
	2 feet long.	1-2 inches long.
	° F.	° F.
June 15, 3 P. M.	70.	71.
7 P. M.	73.	73.9
June 16, 8 A. M.	77.	80.
11 A. M.	78.	82.
2 P. M.	78.5	83.
5 P. M.	78.5	83.4
June 17, 8 A. M.	79.	84.
10 A. M.	78.8	84.
3 P. M.	78.9	84.1
June 18, 8 A. M.	80.	85.
12 M.	80.4	85.5
4 P. M.	81.	85.5
7 P. M.	81.5	86.
June 19, 8 A. M.	84.	88.
3 P. M.	85.	89.
June 20, 8 A. M.	86.	90.
5 P. M.	86.2	90.2
June 21, 8 A. M.	85.	90.
5 P. M.	84.	89.5
June 22, 8 A. M.	83.	89.

In this experiment direct respiration did not reach its maximum as the temperatures were taken some distance below the surface where access of air was somewhat prevented.

Further confirmatory evidence of the influence of the respiration of plant tissues in contact with the air, on the heat produced in masses of vegetable material, is shown by exposing such tissues under conditions where the free access of air is and is not possible. Small masses of corn so exposed showed the following differences in temperature.

TABLE III.— *Temperature of cut corn in air and carbon dioxide gas.*

Time.	Air.	CO_2.	Room.
3 P. M., IX 17	66.	66.	66.
6 P. M., IX 17		70.	68.2
8 A. M., IX 18	101.	68.5	66.5
11 A. M., IX 18	106.	69.4	69.
3 P. M., IX 18	106.	69.4	70.
5 P. M., IX 18	110.	69.5	68.2
8 A. M., IX 19	110.	71.8	71.6
3 P. M., IX 19		73.	75.5
8 A. M., IX 20	102.	74.	71.6
5 P. M., IX 20	100.	73.5	68.2
8 P. M., IX 21	95.	73.	71.

Although in this experiment the conditions were such that radiation from the corn exposed to the air was much greater than in that exposed to CO_2, still the temperature of this mass was much higher than that in which the free oxygen was excluded.

PRODUCTION OF HEAT IN ABSENCE OF OXYGEN.

It should also be noted in the above table that the temperature of the corn kept in a CO_2 atmosphere was somewhat higher than that of the surrounding air of the room. This difference in temperature measures the heat evolved by those physiological processes of the plant known as intramolecular respiration, i. e., the respiratory processes that go on in the absence of free oxygen where the organic matter of vegetable tissues is oxidized by the withdrawal of the combined oxygen from the tissues. It is this set of processes that is most largely operative in the production of heat in an ordinary silo.

An analysis of the gases present in a silo immediately after it is filled shows that the free oxygen of the air-spaces is very rapidly consumed by the direct respiration of the plant cells, and is replaced by CO_2, evolved as an end product of this physiological process.

In a silo, owing to the increase in mass which retards radiation, this heat due to intramolecular respiration is conserved, and as a result, the temperature gradually rises. At the surface where direct respiration is possible, the heat produced will be

much greater, as is evident from Table I. Where a silo is filled slowly, the heat evolved by direct respiration is more pronounced, and as a consequence, the temperature attained in such silos will be greater than those that are more quickly filled.

In relation to this Woll[1] notes that the temperature of deep silos is not likely to exceed 130° F., while if they are slowly filled, the heat may rise to 150° F. or above.

PRODUCTION OF HEAT BY FERMENTATIVE ORGANISMS.

Under conditions where bacteria and such fungi as molds can develop, another factor affecting the heat is introduced. These living organisms also respire, and where accumulated in large numbers, the heat evolved in such a process may be considerable, as is to be noted in the heating of manure or any fermenting material. Where a silo is imperfectly protected from the air, this factor is operative, as these organisms generally need oxygen for their development. Heat from such sources is, however, small when compared with that produced by the direct respiration of plant cells, as is shown in Table I. In this case luxuriant growth of fungi and bacteria was not recognizable until nearly three days after the corn was placed in the container. About this time the maximum temperature was reached as a result of direct respiration, and this high temperature was most favorable to the development of the bacteria and molds. Nevertheless, from this time, the temperature gradually diminished, showing that the heat evolved by bacteria and molds was insufficient to maintain the temperature produced by direct respiration, although bacterial growth was constantly being augmented.

So long as the plant cells are alive the conditions are not favorable for rapid bacterial growth, as no organism of this class is able to develop upon living protoplasm, except those belonging to the relatively restricted group of parasites capable of producing diseases in the vegetable cell. It is only as the wounded cells die that a suitable substratum is furnished for the development of the common saprophytic species of bacteria found on surface of plants. This precludes the possibility of

[1] A Book on Silage, p. 128.

bacteria acting as the heat-generating agents during the first few hours after fodder is ensiled. When silage is removed from the silo after the plant cells have died, bacterial and fungus development is then much more rapid, because they are then able to grow on the dead organic matter. In such cases the rise in temperature often approximates that induced by direct respiration.

In a silo the bacterial and mold development is generally only slight when compared with that which occurs where free oxygen can enter.

An examination of the tissues of ensiled fodders at different stages of the silage-making process carried out as a senior thesis by Mr. H. A. Harding, now of the New York State Agricultural Experiment Station at Geneva, showed that bacteria are to be isolated from such tissues at almost any time, but the number of organisms so found is so small that it does not seem possible that they are able to account for the heating of the silage. To satisfactorily explain the production of heat in such quantities as is to be noted in a silo would necessitate fermentative action of such an extent that it would not be possible to overlook the presence of bacteria.

THE FACTORS EXPLANATORY OF THE INITIAL HEATING OF SILAGE.

To recapitulate: The factors in the initial heating of silage in a silo are as follows:

1. Direct respiration of plant cells.
2. Increase in direct respiration caused by cutting plant tissues.
3. Intramolecular respiration of ensiled material.
4. Respiration of micro-organisms (bacteria and fungi).

Where a silo is filled quickly, the first factor does not function much except at the surface. Where the filling process is discontinuous, this factor is much more important. Under normal conditions, however, the larger amount of heat is attributable to the third factor, and the gradual rise in temperature is due to reduced radiation on account of the mass involved. In a tight silo, the fourth factor is practically negligable. Only in an imperfectly constructed silo is the respiration of the extra-

cellular ferments (bacteria and molds) of any consequence in the initial heating of silage.

ORIGIN OF GASES IN SILOS.

When a silo is made perfectly air-tight, as is possible under experimental conditions, a considerable evolution of gas is to be noted. The composition of the air at time of filling is of course the same as the normal atmosphere, but immediately after the cut fodder is ensiled, absorption of oxygen by the plant tissues begins and continues until all of the free oxygen in the air spaces is consumed by the respiratory processes of the plant. This direct absorption of oxygen is nearly, but not quite, counter-balanced by the evolution of carbon dioxide, as a portion of the oxygen combines to form other by-products. An analysis of the air even within twenty-four hours often shows no free oxygen. The nitrogen of the air is unaffected by these plant processes.

Within a short time gas begins to be given off, and continues at an increasing rate for a day or so, then gradually diminishes. The gas so evolved is largely CO_2, but is mixed with the residual nitrogen of the contained air. This CO_2 is the result of intramolecular rather than direct respiratory processes, and as the oxygen required for this change is derived from the tissues of the plant, the volume of gas in the silo is increased by the amount of CO_2 formed. The evolved CO_2 is therefore a measure of the intramolecular respiration. The evolution of this gas marks an actual and unavoidable loss in the organic matter of silage. This source is operative so long as life exists in the plant cells, but when the cells die, gas from this source is no longer given off.

ASPHYXIATION FROM CARBONIC ACID GAS.

It occasionally happens when the silo is being filled that the carbonic acid gas, which is heavier than air, accumulates over the surface of the silage in such quantities that persons entering a tight silo may become asphyxiated by it. This is more likely to occur when the filling process is interrupted, as from one day

to the next, and may be readily avoided by the introduction of fresh air through the side opening in the silo, or by running in fresh fodder from the cutter. The presence of this gas in dangerous quantities can be readily determined by lowering a lighted lantern which will not burn if the oxygen of the air has been replaced by CO_2.

When the gases of a silo are measured, either by volume or by absorption of the CO_2, the production of gas is found to be very rapid for the first few days, and then to diminish quickly in a manner somewhat comparable to the evolution of heat previously referred to (Fig. 17). It soon reaches (two weeks or so) a rate that continues with slight fluctuations for some months. Such a rate of gas evolution can only be intelligently interpreted by assuming that most, at least, of the CO_2 evolved, is the result of processes inherent to the plant cell, and not to fermentative action set up by organisms which must have developed subsequent to the ensiling of the fodder.

ANALYSIS OF SILAGE GASES.

This conclusion can also be tested in an entirely independent manner by determining the nature of the gases present in the inter-spaces of the ensiled fodder. If bacteria associated with organic decomposition were present in the silage and were at all operative in the production of the gases that are to be found in the silo, the gases known to be evolved in putrefactive or decomposition processes must be present. Where gas-producing bacteria are present there is always formed with the CO_2, a residual gas that is combustible and which is in large part hydrogen, with possibly an admixture in some cases of hydrocarbons (methane, etc.). Where proteid decomposition changes occur (putrefactive processes), ammonia is also produced, but in the formation of this gas, hydro-carbons are likewise evolved.

Applying these principles to a study of the nature of the gases of the silo, it would seem possible to determine independently whether any of such gases were attributable to fermentative processes.

This differentiation can be made by making a combustion

analysis of the gases of the silo that remain after the absorption of the CO_2. When organic gases are passed over ignited oxide of copper, they are oxidized to water and CO_2 which can be collected and determined. This determination was applied to the gases present in two of the small silos (glass carboys holding about 12 gallons) that had been filled with corn such as was used in filling the large silos at the Station farm. One of these silos had been filled 33 days and had been under constant observation during this period as to the rate of gas evolution. For the last two weeks of this period, gas evolution was very slow, and therefore the conditions would be favorable for a determination as to whether the gases were of bacterial or other origin.

The gas from this silo was first passed through an absorption apparatus containing potassium hydrate (KOH) to remove CO_2; then through sulfuric acid (H_2SO_4) and calcium chloride ($Ca\ Cl_2$) to remove the moisture. The gas was then passed through a combustion tube filled with oxide of copper heated to redness. Under such conditions, hydrogen will abstract oxygen from the copper oxide and water will be formed. If a hydrocarbon is present, it will be oxidized to CO_2 and water. If these products are absent, it proves that neither free hydrogen nor any hydrocarbon gas could be present in the silo air.

The products of combustion were then passed through a weighed $Ca\ Cl_2$ tube to absorb the water and afterwards through barium hydrate ($Ba\ (OH)_2$) to detect CO_2. A tell-tale of $Ba\ (OH)_2$ was interposed between the KOH and the H_2SO_4 absorption tubes to show whether all CO_2 was caught by the KOH. The result of this experiment showed the presence of neither hydrogen nor hydrocarbon even after 10 liters of gas had been drawn from the silo.

This test was repeated with another silo that had been filled only twelve days and the same results were obtained. In this case the evolution of gas from the silo had practically ceased.

The conclusion from these experiments confirms the hypothesis already advanced that the gases of the silo are of such a nature that they could not be produced by the action of such fermentative organisms as bacteria.

RELATION OF INITIAL HEATING TO SILAGE FORMATION.

Inasmuch as under normal conditions silage always generates more or less heat when it is first ensiled, the popular opinion is that the making of good silage is necessarily accompanied by the evolution of considerable quantities of heat. Fry[1] of England even goes so far as to state that sweet silage can not be produced unless the initial heat exceeds a temperature of 122° F. (50° C.).

In our study of this question, we have followed the practice of ensiling small quantities of fodder in vessels ranging from a pint to several gallons capacity. Under these conditions the heat generated by the respiratory processes of the vegetable tissue has been readily dissipated by radiation. In some cases these experiments were controlled by exposing these small vessels continuously at a temperature ranging from 120° F. to 140° F. The result of these trials showed that when other conditions were favorable, just as good silage could be made in small receivers where the temperature did not at any time exceed that of the room (60–70° F.), as in large silos where the initial heat is much higher; thus showing that the accumulation of heat which naturally occurs in a silo when large masses of fodder are ensiled, is not at all essential for the production of good silage.

CAUSES OF CHANGES IN THE FORMATION OF SILAGE.

A comparison of the chemical composition of green corn and silage shows that the latter invariably contains an increased amount of organic acids, a diminished amount of carbohydrates, and to a less marked extent, albuminoids. In general all writers upon this problem have ascribed the changes produced to direct fermentative action[2] (acetic, lactic and butyric bacteria).

But the evidence adduced to support this view is far from being satisfactory and conclusive. Some of the phenomena ordinarily associated with silage production seemed, in our judgment, to be explained quite as well by other than bacterial

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[1] Theory and Practice of Sweet Ensilage, p. 16.

[2] Lafar, Technical Mycology, p. 261; Conn, Story of Germ Life, p. 113; Wollney, Die Zersetzung d. Organischen Stoffe, p. 450.

changes, and accordingly investigations were begun several years ago to determine with certainty whether bacteria were the effective agents in the production of good silage.

The preliminary work on this subject was carried out, under our direction, by Mr. H. A. Harding. In his thesis he found that when fodder crops were kept in closed receptacles, the atmosphere of which was saturated with ether, that typical silage was produced. These experiments were then repeated on a larger scale with other anaesthetics (chloroform and benzol), and confirmatory results obtained. In such cases, change in color, some increase in acidity, and typical silage flavors were produced. These results seemed to indicate that the processes of silage production were able to go on in the presence of an agent which was supposed to inhibit bacterial development.

Similar experiments have been made each year since these were first conducted in 1897, and entirely concordant results obtained. Silage thus made, under these anaesthetic conditions, differs from that normally found in large silos only by having less acidity, and sometimes a less marked aromatic odor. Such silage, after the evaporation of the volatile anaesthetic, was readily eaten by animals. Similar results have also been repeatedly obtained where different varieties of apples were placed under the same conditions.

The conditions of these experiments prevented the action of bacteria and other living organisms, and excluded these organisms as a necessary factor in explaining the changes involved in the formation of silage. How then can these results be explained? It would seem from the above experiments that the cause of the changes must reside in the plant cell itself.

EXPLANATORY HYPOTHESES SUGGESTED.

Two possible hypotheses suggest themselves as throwing light on these phenomena.

1. Changes inaugurated and controlled by the protoplasm of the plant cell itself.

2. Changes occasioned by the action of enzymes derived from the plant cells.

Protoplasm and enzymes derived from the same are so closely

related in their activity that it is impossible to wholly differentiate one from the other. The intramolecular changes which occur in protoplasm where ordinary metabolic processes are suspended, by reason of oxygen exclusion, always results in the formation of organic acids, and in a partial degradation of the albuminoids.

The intramolecular processes depend upon the duration of the vitality of the cell and are manifestly less where the environmental conditions are such as to hasten death. This may be the explanation of the fact that the fodder preserved in the presence of ether and other anaesthetics, which cause a quick suspension of the vital activities of both the bacterial and plant protoplasm, has less acidity. The fact that the peculiar aroma and change in color occur in the ether silage would indicate that these changes are not due to the direct action of the living protoplasm of the plant, as the ether quickly causes a cessation of the functional activity of the protoplasm. If, however, bodies of the nature of enzymes are produced by the plant cell, they would still be operative in the presence of such anaesthetics as have been used. It is well known that in this dying of protoplasm such chemical ferments are frequently released, as has been determined by Loew[1] in investigations on the changes which take place in the curing of tobacco.

If it were possible to prolong the life of the plant cells in an atmosphere devoid of free oxygen, and so increase the by-products of intramolecular respiration, then it would seem probable that the amount of organic acids formed in the silage would be greater than where cell death was hastened. This was accomplished by placing the cut fodder in closed vessels filled with different gases (hydrogen, nitrogen and carbon dioxide) in order to exclude oxygen without the immediate suspension of life. In these experiments,[2] the fodder exposed to hydrogen and to nitrogen retained its green color much longer than that in carbon dioxide, and it was found by respiration tests that the corn exposed to CO_2 died much quicker than was the case where the tis-

[1] **Loew, Rept. 59. Div. V. P. P. U. S. Dept. of Agri.**

[2] **The detail of these and a number of the following experiments made in 1900 was carried out by our assistant, Mr. E. G. Hastings.**

sues were placed in the more inert gas and the CO_2 that was evolved by intramolecular processes absorbed.

To recapitulate: Those forces which hasten the death of the plant tissues (CO_2, ether, etc.,) result in the preservation of the fodder with a minimum production of acid products. On the other hand when the functional activity of the protoplasm is prolonged, as in nitrogen and hydrogen, the amount of acid products is very considerably increased and the nutritive value of such fodders much impaired. If this principle is operative it is easy to see the beneficial effect of CO_2 in a silo as this gas causes a more rapid death of the cells and thus reduces the unavoidable losses.

This quicker cell death in CO_2 is explained by the well known toxic action of this gas in comparison with the more inert hydrogen or nitrogen. The silage in these inert gases produced considerably more organic acids than in CO_2, thus showing that the increase in amount of these by-products of intramolecular respiration was due to a prolongation of the life of the plant cells.

This conclusion is still further strengthened by experiments made with corn fodder ensiled at different stages of its maturity.

INFLUENCE OF MATURITY OF CORN ON QUALITY OF SILAGE.

During the growing period of any plant, the protoplasm is in a much more active condition than it is in the more mature stage, when the function of fruiting has been more or less completed. It therefore follows that any phenomenon dependent upon the functional activity of the protoplasm of the plant cells will be likely to be more pronounced during those stages when such activity is greatest. Inasmuch as protoplasm is undoubtedly more active, and possibly more abundant, during the period of inflorescence, than it is during the ripening of the fruit, it is also evident that the intramolecular processes would be continued longer, and therefore, the by-products of such activity (organic acids and CO_2), would be produced in larger amount, during this earlier and more active period.

Applying this physiological principle to the ensiling of corn, we have found that when such tissues were ensiled as early as the "tasseling" period, that the amount of acid products was greatly

increased in comparison with that noted when the ear was "in the dough," or even more mature. Such fodder would generally be classed as "sour" silage. Not only was there this sharp difference in acidity, but even the color and aroma of the immature corn differed from the other.

In the immature corn, no distinctively silage aroma was present, it retaining the odor and flavor of preserved green tissue, except as masked by the sharply acid taste. Where these ensiled tissues were kept under silage conditions, a pronounced disagreeable odor was sometimes present that resembled incipient putrefaction. In time the tissues became softened, especially about the nodes of the stem. A bacterial examination of these immature tissues showed presence of anaerobic bacteria.

Where corn of such maturity as is generally used for silage was exposed under similar conditions, the normal aromatic odor was produced. In no case did such silage show any putrefactive changes. This same general principle was also shown where apples of varying stages of maturity were ensiled with and without anaesthetics.

The explanation of these differences is quite evident in the light of the general physiological law advanced. The more immature, and therefore more active tissues underwent more profound intramolecular changes; and as a consequence, the acidity of the silage was much greater. The production of incipient putrefactive odors, which very greatly impair the palatability of the fodder, is unquestionably due not to the intramolecular plant changes, but to the decomposition products formed by bacteria capable of thriving in these dead organic tissues under anaerobic conditions.

Not only is the quality of the silage affected by these changes incident to the immature condition of the ensiled tissues, but the actual and unavoidable losses are to be ascribed to the same source; and are much larger under these conditions than they are with the more mature corn, provided the silo is constructed so as to exclude air which would directly promote the growth of molds and bacteria.

These results while obtained in the laboratory on a small scale are abundantly confirmed by the experience of those who have

attempted to ensile corn in a too immature condition. It is the general experience of all that such fodders are extremely sour, and often contain putrefactive products in sufficient amounts as to be denominated "rotten silage." So far as the corn plant is concerned, it would seem that the production of the peculiar properties incident to silage of first quality is associated with a certain degree of maturity of the plant. Practical experience has generally shown that this stage is when the ear is in the dough or somewhat later.

Other plants such as clover, peas, oats, and different cereals have been used for ensiling purposes, but in many cases with unfavorable results, although at times with clover at least, excellent silage has been obtained. Whether it is possible to apply the above principle to these various forage crops is yet a question. It is barely possible that a more mature condition of these fodders would give satisfactory results. Experiments are in progress to test whether this principle is general in its application.

CONCLUSIONS.

The results of our experiments in making silage under laboratory conditions lead us to the conclusion that the generally accepted theory of silage formation as due wholly to bacteria does not rest on a sound experimental basis; inasmuch, as it has been possible to make good silage under conditions which exclude bacterial activity, viz., in the presence of anaesthetics such as ether, chloroform and benzol.

The cause of the initial heating of silage which has heretofore been generally ascribed to the action of various types of bacterial fermentation has been shown to be due mainly to the respiratory processes of the cut plant tissues themselves. Bacteria and molds function in a very minor capacity in properly constructed silos where air is excluded.

The gases of a silo are carbon dioxide and nitrogen, the carbon dioxide being evolved by the intramolecular respiration of the ensiled tissues, while the nitrogen is simply due to the entangled atmospheric air that is originally present when the silo is filled. In good silage where putrefactive changes do not occur, the gases

associated with bacterial fermentation (hydrogen, ammonia and volatile hydrocarbons) are not found.

The popular opinion that good silage cannot be made unless accompanied by the generation of considerable heat when the fodder is first ensiled has been proven to be erroneous, as first class quality of corn silage has been produced in numerous instances in small receivers, the temperature of which at no time exceeded 75–80° F.

The peculiar changes that characterize the formation of good silage are not due to the activity of various external ferments such as bacteria, etc., but to changes inaugurated and under the more or less direct control of the protoplasm of the plant tissues that are ensiled. The acids of silage seem to be for the most part a product of the intramolecular respiration, and in quantity are roughly proportional to the length of time that ensues before the cells stop respiring.

As these processes are continued in immature and succulent plant tissues for a longer time than where the cells have reached their maturity, it naturally follows that the amount of acids present in silage made from immature corn is much greater than where more nearly matured fodder is ensiled. Not only is silage from immature corn of higher acidity, but putrefactive changes occur, due to the fact that bacteria capable of developing under anaerobic conditions are able to grow in the more succulent tissues.

The peculiar aroma of good silage can be produced under conditions in which all vital processes are suspended. This seems to point strongly to the idea that enzymes are operative in the production of this characteristic. It has been shown by others that in the drying of vegetable cells, such ferment bodies are liberated from plant protoplasm, and may continue to act after the cells lose their vitality.

The unavoidable losses in silage are due to the formation of water, carbon dioxide, and volatile organic acids which are produced as a result of the intramolecular respiratory processes of the ensiled tissues. As these changes are prolonged in the more active and immature tissues in comparison with the more mature, the losses in the first case are greater.

The avoidable losses, on the other hand, are due mainly to the decomposition of organic matter induced by the development of bacteria and molds, the growth of which is greatly facilitated by the admission of air as a result of the imperfect construction of the silo. This same imperfection also prolongs the direct respiration of the plant tissues, thereby increasing the amount of water and carbon dioxide produced.

The bacteria, instead of functioning as the essential cause of the changes produced in good silage, are, on the contrary, only deleterious. It is only where putrefactive changes occur that their influence becomes marked.

If the theories advanced in this paper are confirmed by subsequent investigation, their recognition as explaining the causes of silage changes will enable the farmer to see the necessity of exercising greater care in the construction of air-tight silos, and the selection of fodder of proper maturity, so as to eliminate the avoidable losses and reduce to a minimum those inherent changes incident to the protoplasmic processes themselves.

A CLOSED CIRCUIT RESPIRATION APPARATUS.

S. M. BABCOCK AND H. L. RUSSELL.

In the course of some investigations on the relations of respiration of vegetable tissues (see page 125) to the production of heat in silage, it became necessary to carry on this work under a number of different conditions, not only with reference to the gaseous environment used, but also to study the influence of various volatile plant poisons. While the ordinary Pettenkoffer respiration apparatus, as originally described by him, or subsequently modified by Pfeffer and others, satisfies the requirements of work usually performed in this line, it seemed desirable to economize in the production of the gases used (hydrogen and nitrogen), inasmuch as it was necessary to use them in a perfectly pure condition. This was accomplished by the use of the following apparatus in which a closed circuit permitted a limited quantity of gas to be used over and over with or without the addition of any volatile substance, the effect of which it was desirable to study.

PRINCIPLES OF THE APPARATUS.

The circulation of gas is secured by utilizing a Bunsen pump (B. P. in cut), which permits of the maintenance of a normal pressure in the respiration chamber (R. C.).

At the outlet of the Bunsen pump, the pressure is increased while at the inlet it is reduced. An equilibrium may be maintained in the respiration chamber by adjusting the height of the overflow (Ov.) so that it equals the resistance of the potash towers (A, A^1; B).

In connection with the usual potash towers (A, A^1) for the absorption of CO_2, pyrogallic acid may be added to one when the

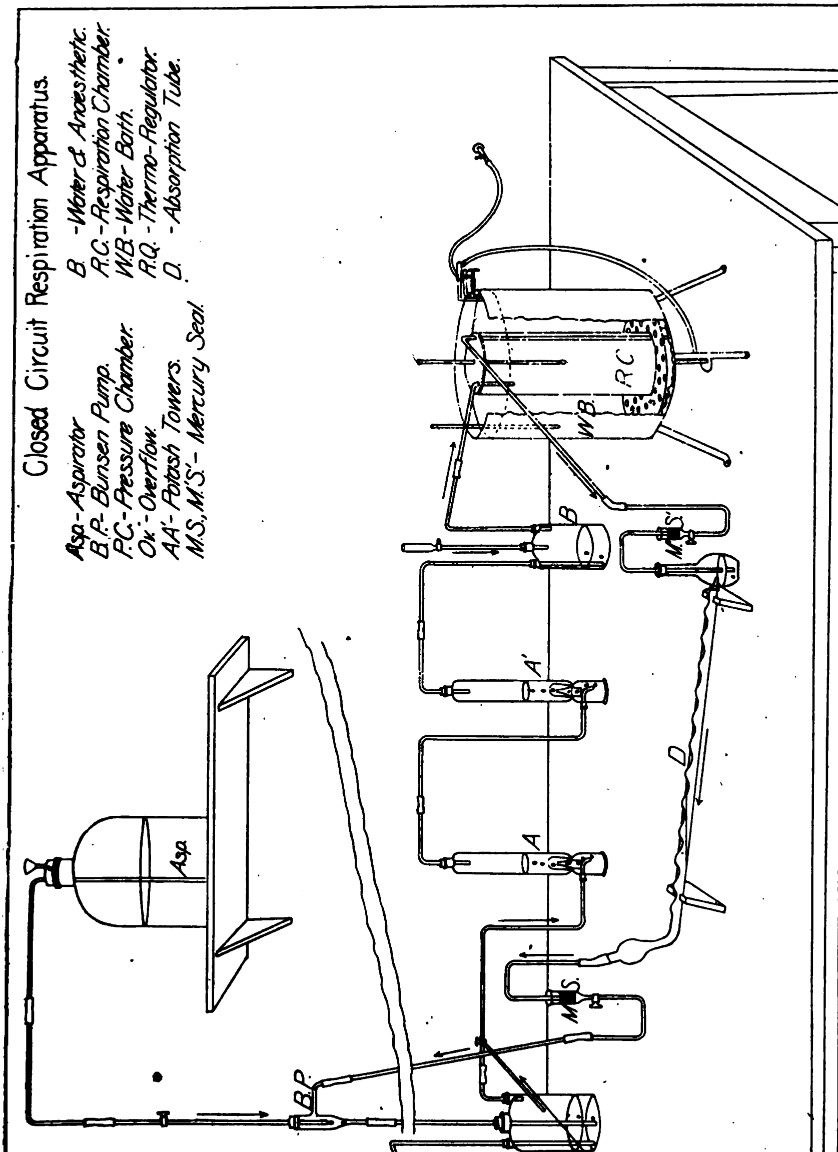

FIG. 18.—General view of respiration apparatus.

apparatus is used under anaerobic conditions in order to guard against leakage of oxygen. To permit of the more ready absorption of the CO_2 the air is made to bubble through a tubulated glass "breaker" (b and b[1], Fig. 19, A) which retards the passage and forms smaller bubbles. The next flask in this circuit (B) is used to moisten the air and charge it with anaesthetic vapor if this modification is desired. If chloroform is used the entire circuit must be hooded as this anaesthetic is decomposed by light, forming HCl which would then be absorbed by the barium hydrate.

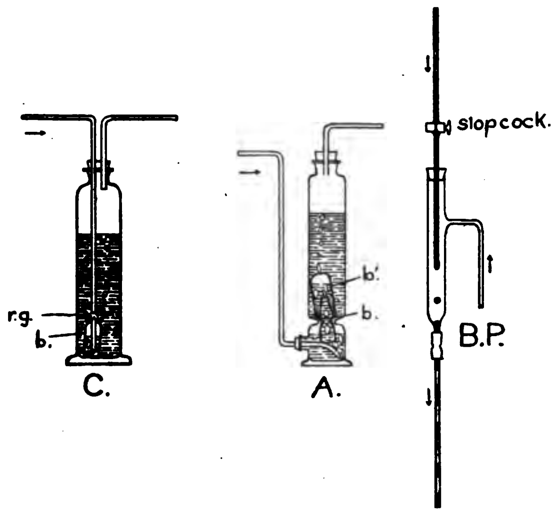

FIG.19.—Detail of absorption apparatus and Bunsen pump.
A. Potash absorption tower; *b*, *b*[1], tubulated glass "breakers" to retard passage of bubbles.
C. Absorption tower for respiration products; *b*, "breaker" held in place by rubber guard, *r. g.* This form facilitates removal of barium hydrate for titration.
B. P. Bunsen Pump.

ABSORPTION OF CO_2.

Instead of the ordinary Pettenkofer absorption tube, we have used two kinds of absorption apparatus. The first differs from the Pettenkofer tube in having an irregular instead of a uniform bore, produced by blowing out and denting the glass walls (See D, Fig. 18 or Fig. 20). These irregularities are confined to the upper surface and serve to break up and hold the air bubbles so that the CO_2 is more readily absorbed. In a tube ar-

ranged in this way the movement of the CO_2 bubble is retarded and its surface broken at each irregularity. The lower side of the tube should not be indented as this interferes with the removal of the precipitate formed.

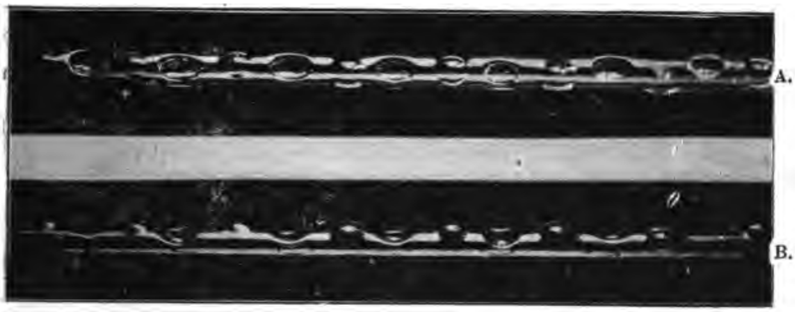

FIG. 20.—Absorption tube for carbon dioxid.
Modification of Pettenkofer tube made by indenting and blowing out upper and lateral faces of tube so as to produce irregularities that will retard the rate of flow of gas bubbles, thus permitting more ready absorption.
A—View from above.
B—View from side.

Instead of the usual rubber connections, the absorption tube can be fitted with mercury seals (m. s., m.′ s.′, Fig. 18) so as to facilitate the removal of the apparatus.

Where large amounts of respiring tissue are employed, it is advisable to substitute a battery of absorption towers (C in Fig. 19). In order to retard the passage of the CO_2 gas through the barium hydrate, these are provided with a "breaker" which is kept from rising to the surface by a rubber guard (r. g., Fig. 19C). Generally these towers have been used in a series and titrated when the second one of the series was still alkaline, leaving the third as a tell-tale. If phenophthalein is added to each, the progressive neutralization can be determined by the eye. When mixed, the contents of all flasks showing turbidity should have an alkaline reaction as otherwise it is necessary to titrate back.

The residual atmosphere after it leaves the absorption towers, returns to the Bunsen pump, thereby establishing a continuous circuit. The only leakage which occurs is through absorption of gases and vapors by the water which feeds the pump. In the case of anaesthetics readily soluble in water (ether), this loss is

appreciable, and hence necessitates an occasional renewal in the anaesthetic flasks (B).

When surface water such as lake water is used in the aspirator, it is advisable to filter through absorbent cotton to remove algae and suspended particles which would otherwise clog the stopcock in the Bunsen pump. The rate of circulation in the apparatus is readily controlled by changing the rate of flow in the aspirator.

THERMAL DEATH POINT OF TUBERCLE BACILLI UNDER COMMERCIAL CONDITIONS.

H. L. RUSSELL AND E. G. HASTINGS.

The importance of determining the actual temperature at which disease-producing bacteria are destroyed by the application of heat is at once evident, for such a determination is necessary in selecting the limits set for the destruction of such bacteria in food or elsewhere.

IMPORTANCE OF TIME AND TEMPERATURE.

In the determination of the death point of any organism by means of heat, two factors must always be taken into consideration, viz., temperature and time.

In applying a degree of heat which is just sufficient to destroy bacteria, or in fact, any living organism, animal or vegetable, a variation in temperature is accompanied by an inverse variation in length of exposure. If the temperature is increased, a briefer exposure is sufficient to accomplish the same result. If, on the other hand, a somewhat lower heat is applied, it will require a longer time to kill. The importance of this time relation may be readily shown by the reaction experienced if the hand is plunged into hot water. A person may bear the hand in scalding water for a second or so without serious injury, but prolong the exposure some moments, and scalding results, i. e., the living cells of the tissues are killed by the action of the hot water.

In stating the thermal death point it is advisable to have a standard length of exposure, so that the variation in the vitality of different forms may then be expressed in the temperature necessary to kill the same, when the exposure is made under these uniform conditions. For this purpose a ten minute exposure is

usually selected as a standard, and when not otherwise expressly stated, a thermal death point is generally referred to such an interval.

Bacteria of all sorts are, as a rule, more resistant than the more highly organized tissues of higher plants and animals. For this reason, they are able to withstand a degree of heat that would be quickly fatal to other forms of life. Another factor that renders some of the bacteria even more resistant than usual is the ability of certain species to produce spores or resistant structures that from a physiological point of view are acted upon in the same manner by external conditions as are the seeds of higher plants. When bacteria form spores they become still more difficult to kill. It is this factor that renders it necessary to use such stringent measures in the disinfection of some diseases.

Fortunately, most of the pathogenic or disease-producing bacteria do not form these spores; and therefore, in their vegetative or growing stage, they can be more readily destroyed.

THERMAL DEATH POINT OF TUBERCLE BACILLUS.

More than usual interest has centered in the determination of thermal death limits of the tubercle bacillus, for the following reasons.

1. Previous determinations seem to have indicated that while this bacillus did not possess the property of forming spores, still it required a higher degree of heat to destroy the same than was necessary with other disease-producing bacteria.

2. The fact that milk as it is derived directly from the animal sometimes contains this organism makes it very important that there be a thoroughly reliable determination of the degree of heat necessary to kill the same, especially in milk.

It will be unnecessary in this connection to go into the full details reached by previous observers as to the point at which this germ is destroyed. Reviewing the work which has been done, it is evident that there is considerable discrepancy in the results that have been obtained. The reasons for this variation are not altogether obvious, but in part at least they may be attributable

to the fact that the conditions under which the thermal death point has been determined have not been uniform in all cases. In some instances tuberculous tissue has been employed, ranging from macerated tuberculous nodules to the semi-fluid cheesy pus formed in the later stages of the disease. In other cases, pure cultures of the tubercle organism have been employed. Again, the exposures have been made in various fluids, such as water, beef broth, milk, etc. Still another condition that might affect the accuracy of investigations is the fact that the tubercle bacillus grows so slowly and with such difficulty on media other than that specially prepared for its development that direct determinations of the vitality of the organism can not be made. It is necessary therefore in ascertaining whether the germ has been killed or not to make artificial inoculations in animals of the organisms tested, and to determine by the subsequent development of the disease in such animals whether the germ was dead or not when inoculated. This indirect method of operation is perhaps open to some theoretical objection, but all things considered, it is preferable to any other that has been proposed.

The standards that have been most commonly accepted are those of de Man[1] who worked with broken-down semi-fluid cheesy matter derived from tuberculous udders.

His results are summarized as follows:

TABLE I.— *Thermal death limits of tubercle bacillus.*

Temperature	Time of exposure.
55° C. (131° F.)	4 hours.
60° C. (140° F.)	1 hour.
65° C. (149° F.)	15 minutes.
70° C. (158° F.)	10 minutes.
80° C. (176° F.)	5 minutes.
90° C. (194° F.)	2 minutes.
95° C. (203° F.)	1 minute.

The results of other investigators have differed some from de Man's data. In several instances observers have noted that a somewhat shorter exposure was generally sufficient to kill; but in practical work, such as the pasteurization of milk, where it is especially desirable that this food product be treated under con-

[1] Arch. f. Hyg., 1893, 18:133.

ditions that will insure the destruction of the tubercle bacillus, the limits as determined by de Man have generally been followed.

RECENT INVESTIGATIONS ON THERMAL DEATH POINT OF TUBERCLE BACILLUS.

Within the last year, however, this question has again been reopened through the investigations of Prof. Theobald Smith[1] of the Harvard Medical School.

In a most carefully controlled series of investigations with tubercular organisms derived from different sources, he has made a comparative study of the time necessary to kill the tubercle bacillus when exposed in a moist medium at the standard temperature of 60° C. (140° F.). His conclusions differ from those of the majority of previous workers, in that he finds that the tubercle bacillus is destroyed more quickly than has heretofore been considered possible. An exposure in distilled water, dilute salt solution (0.6 per cent.), and bouillon, for 15 to 20 minutes at 60° C. (140° F.) is sufficient to kill all tubercle bacilli. The majority are killed in 5 to 10 minutes.

In milk, however, he found discordant results. If the exposure took place in milk, the surface of which was exposed to the air, then it required a much longer time to effectually destroy the organism. Where the milk, however, was heated in closed receptacles as in sealed thin walled glass tubes, it was no more resistant than in any other liquid.

These results are of such importance to dairying, especially in the pasteurization of milk, that they certainly need to be retested under conditions that more nearly conform to those practiced in the commercial handling of milk.

RELATION OF TEMPERATURE TO CONSISTENCY OF PASTEURIZED MILK AND CREAM.

The commercial limit of pasteurization that has been followed in this country is an exposure at 65°–68°C. (149–155°F.) for 15–20 minutes, but at this temperature the viscosity or consist-

[1] Journ. of Expt. Med., 1899, 4:217.

ency of milk or cream is considerably diminished. Babcock and Russell[1] have previously shown that this diminished "body" is due largely to the mechanical aggregation of the fat globules in the milk or cream. Under normal conditions the fat globules instead of being homogeneously distributed throughout the milk serum are collected in microscopic clots and when heat is applied to milk at a temperature above 60° C., these fat globule aggregations are broken down and the globules are uniformly distributed throughout the serum. This does not occur until the milk is exposed to a temperature above 60° C. Milk heated in this way does not cream readily and the "body" of cream itself is materially lessened. To the consumer this is a decided objection, as he naturally associates this condition with inferior and less valuable products. To avoid this difficulty, milk must be heated at a temperature not exceeding 60° C., but with the old standards (de Man's) as to the thermal death point of the tubercle bacillus, a treatment at the temperature of 60° C., would require an exposure of at least an hour, a period that would be impractical to use in the commercial handling of this product.

If, however, the tubercle bacillus of bovine origin is destroyed at 60° C., in a much shorter period of time, as asserted by Smith, then it will be possible to formulate a new standard for commercial pasteurization that will overcome the only objection that has heretofore been urged against this product.

OUTLINE OF EXPERIMENTAL WORK.

In carrying out a retest of this work, we have conformed as far as possible to the conditions that would obtain in commercial pasteurization, so as to make the work directly applicable to the needs of this branch of the dairy industry. The tests have therefore been made in a commercial pasteurizer (Pott's pasteurizer) which is in constant use in the University Creamery.

Naturally one might think that the milk to be tested in such work ought to be from tuberculous animals in which the disease germs were actually present in the milk; but there are stronger reasons for using milk infected in other than the natural way. Had naturally tuberculous milk been available at the time the

[1] 13 Rept. Wis. Expt. Station, 1896, p. 73.

tests were being made, a series of experiments at least would have been attempted, but in our experience we have found the milk of animals reacting to the tuberculin test to contain the tubercle bacilli only in rare cases; and although endeavors were made to find an animal having tubercle bacilli in the udder, it was impossible to secure a sample. It was therefore necessary to use pure cultures of the tubercle bacillus that had been isolated from bovine sources. In this way it was possible to unify the results and make them much more comparable than it would have been had diseased milk from various sources been employed.

Then again, in this way the number of bacilli per cubic centimeter was much greater than it would have been in naturally tuberculous milk, thus making the conditions more severe and crucial. It may be thought that the vitality of the organism would, perhaps, be lessened by artificial cultivation for varying periods of time in comparison with what it would be if taken directly from the diseased animal. In caseous material from tubercular growths, the living bacilli would not be actively developing and might be more resistant; but in the experiments detailed by Smith,[1] no increase in resistance to heat was noted where broken down tubercular discharges were used directly.

In order to insure average conditions, several cultures from different sources were used. The exact history of each had been traced, as to their origin, time of cultivation on artificial media, and virulence; with this data at hand, it was possible to determine with exactness whether artificial cultivation had in any way weakened the virulence of the same.

VIRULENCE OF PURE CULTURES USED.

To show more fully that cultivation on artificial media had not weakened the pathogenic properties of the cultures used, the following data are presented:

[1] Journ. of Expt. Med., 1899, 4:222.

TABLE II.—*Date as to origin of cultures, virulence, etc.*

Name of culture.	Origin.	When isolated.	Time of Cultivation. Series.	Mos.	Days.	Period of incubation of disease in guinea pigs at time of test.
Smith (III).....	Bovine direct...	April 19, 1897.	I	30	7	18
			II	33	14	13
Ravenel (H)....	Bovine direct....	July 6, 1899.	III	6	10	17
Ravenel (C)....	'Supposedly bovine from horse	Jan. 28, 1899.	V	13	0	19

Although attention has been called by de Schweinitz[1] to the fact that the tubercle organism slowly loses its virulence if it is cultivated on artificial media for a long time, still Smith[2] has shown that this attenuation does not always occur even after cultivation for several years. From the period of incubation of the disease when artificially inoculated into the abdominal cavity of guinea pigs, it is evident that the cultures used in these experiments were practically the same in virulence.

The culture used in Series I and IV although cultivated for the longest period of time was fully equal in virulence to the other cultures that had been isolated for only one-fifth to one-third as long.

HISTORY AND ORIGIN OF CULTURES USED.[3]

Th. Smith (III). Culture obtained in June, 1899, from Professor Theobald Smith, of Harvard Medical School, Boston, Mass. History of culture as follows: Original culture made from tissues of a cow killed March 19, 1897, at Brighton (Boston) abattoir. Animal had extensive lesions of tuberculosis in lungs and liver. Cultivated on artificial media since April 19, 1897.

[1] 15th Rept. Bureau Animal Industry, 1898, p. 318.

[2] l. c.

[3] It is with pleasure that we acknowledge our indebtedness to Professor Theobald Smith, of Boston, and to Dr. M. P. Ravenel, of Philadelphia for their kindness in furnishing us pure cultures of this organism with the data as to origin of the same.

Ravenel (*H*). Culture received November 23, 1899, from Dr. M. P. Ravenel, Bacteriologist of the Pennsylvania Live Stock Sanitary Commission. Culture isolated July 6, 1899, from a guinea pig inoculated May 17, with cheesy material from a tuberculous mesenteric gland of a Jersey cow. Virulence as determined by Ravenel was as follows:

Guinea pigs (sub-cutaneous)	28 days.
Rabbits (sub-cutaneous)	56 days.
Dogs (intra-pulmonary)	61 days.
Goats (intra-pulmonary)	24 days.
Swine (intestinal by feeding)	69 days.

Ravenel (*C*). Received culture (6th transfer) from Dr. Ravenel, February 8, 1900. Culture isolated January 28, 1899, from a horse that had been kept in a stable with a herd of 18 cows, 11 of which were killed because of bovine tuberculosis. Primary source of infection undoubtedly bovine.

METHODS USED IN FOLLOWING INVESTIGATIONS.

Method of securing tuberculous milk. The age of each pure culture used for the different tests was as follows:

Series	I	II	III	IV	V
Age in days	36	34	27	27	18

The sub-cultures transferred from the original pure cultures were incubated at 37° C., in closed tubes with air vent on dog's blood serum. Growth was removed from surface of medium, transferred to sterile tube and ground up with 0.6 per cent. sterile NaCl solution until apparently homogeneous. The suspension thus made was densely turbid. This was then placed in refrigerator over night, so as to allow coarser particles to settle. Stained cover glass preparations were then made from these suspensions in order to gain an idea of the relative number of organisms and their distribution. The tubercle bacillus was generally so abundant in these preparations that almost every field under high power showed the presence of the specific organism, isolated, or in clumps ranging from a few bacilli to occasionally a hundred or more.

The milk used as a menstruum was drawn directly into a sterile flask at about the middle of the milking, and to a portion of this full milk, a given quantity of the salt solution containing the bacilli was added. This milk was therefore highly charged with the organism of tubercle, and as the exposure was made in raw milk, the conditions were practically the same as they would have been had infected milk been drawn from the animal. The specific organism, however, was much more numerous than it would ever likely be in milk coming from a diseased animal.

Method of pasteurizing the milk. The heating of the infected milk was done in a rotating commercial pasteurizer (Pott's) that is in daily use in the University Creamery. This apparatus handles the milk in an intermittent manner, i. e., a definite quantity being treated for any desired time. This is then withdrawn and a second portion handled if necessary. In this way every particle of milk is subjected to the desired temperature for any period of time.

As it would require an enormous amount of culture growth to infect the apparatus full of milk, the following method of handling the infected sample was devised. Test tubes of moderately heavy glass were partially filled with fresh milk to which the tuberculous suspension had been added. These were then closed with a cork and rubber guards placed over the ends of each tube to prevent the same from breaking when rotated in the pasteurizer which was filled as usual.

The machine was first heated to the desired temperature 60° C. (140° F.), the infected samples being quickly heated in a water bath outside. They were then placed in the pasteurizer, which was rotated for the requisite lengths of time. The samples were then removed, cooled quickly in cold water, after which they were ready to be inoculated into the test animals.

By first bringing the temperature of the infected samples to the proper pasteurizing point, 60° C., it was possible to maintain the temperature of the apparatus more nearly constant and at the same time subject the samples to the preliminary heating previous to 60° C. for a shorter period of time. In this way the cultures were only exposed to a temperature between 45° C. (113° F.) and 60° C. (140° F.) from two to five minutes. It is diffi-

cult to hold the temperature of the pasteurizing machine at an absolutely constant temperature, but the fluctuation did not vary more than a single degree from the proper point, and then this variation was only for a moment.

Method of testing vitality of heated organism. Owing to the fact that the tubercle bacillus does not grow readily in artificial media, it is necessary to use some other that the usual cultural methods in determining whether the organism had been killed or not. For this purpose animal inoculations are necessary. The tubercle bacillus is capable of developing in almost all of the warm-blooded animals, but the guinea pig is *par excellence* the best adapted for this purpose, as it is more susceptible to this disease than any other animal that would be available.

In inoculating these animals the material to be tested was uniformly introduced into the body cavity (intra-peritoneal injection) as this is the most susceptible point where successful inoculation can be practiced. In this way if the tubercle bacillus survived the pasteurizing treatment, it would be placed under conditions where growth was readily possible, and the progress of its development could be noted by the onset of the disease in the animal, which development could finally be confirmed by a post mortem examination of the pig after it had died or been killed.

The progress of the disease in this animal is relatively slow when compared with the action of most disease-producing bacteria, yet the post-mortem examination reveals the course and extent of the malady, and shows in a conclusive way, the relative virulence of the cultures heated for varying periods of time.

It sometimes happens that when large doses of culture material are injected that nodules will be formed even though there are no living bacilli in the material injected. Pathological changes of this sort are due to the action of the tubercular poisons thrown off by the cells in their development. It is possible, however, to differentiate such lesions from those produced by living tubercle bacilli by their distribution in the animal and the relation they bear to the point of inoculation.

Where the inoculated animals did not die from tuberculosis they were chloroformed after a lapse of a considerable period

(several months) and a careful post mortem examination made. Such lesions as could not be diagnosed with certainty from the gross anatomical appearance were hardened, sectioned and studied microscopically.

EXPERIMENTAL RESULTS.

The following Series (I–V) detailed below were made with milk that had been heated in a commercial rotary pasteurizer (Pott's machine). Exposures were made for varying periods of time and guinea pigs inoculated with the heated milk in the manner previously described. Generally, two animals were injected with milk from each lot so as to more perfectly control the results. In all cases animals were kept under similar conditions. The detailed results of each series are herewith presented with a brief summary of the post-mortem records made.

TABLE III.—*Experiments on thermal death point of tubercle bacillus.*

Series I.—Origin of culture: Bovine (Th. Smith III).

Lab. No.	Time of exposure. (Min.)	Quantity injected. (c. c.)	Weight of Animal.		Period of incubation. (Days.)	Result.	Remarks.
			Initial. (Gms.)	Final. (Gms.)			
1	0	1.6	419	332	18	+*	Acute generalized tuberculosis.
2	15	1.6	527	513	28	—	Died from intestinal trouble; no tuberculosis.
3	15	0.8	446	285	80	—	No trace of tubercle lesions.
4	30	1.6	464	465	133	—	No symptoms of tubercle.
5	30	0.8	398	300	47	—	No tuberculosis.
6	45	1.5	470	321	35	—	No tuberculosis.
7	45	0.8	464	422	27	—	Died from bowel trouble; no tuberculosis.

* + = tuberculosis; — = healthy.

DETAILS OF SERIES I.

Age of culture when used 36 days.

Suspension of bacilli made in 0.6% Na Cl solution, 2 cc. of this suspension being added to 3 cc. of milk for each time period.

Inoculations made in duplicate of all heated samples. In this

series a number of the animals died from other troubles than tuberculosis. The post mortem examinations showed pathological changes in stomach and intestines; the primal source of trouble being probably that they were overfed.

Post mortem notes. No. 1. Acute generalized tuberculosis.—Lymph glands of thigh enlarged. Peritoneum studded with numerous small tubercles. Liver badly affected. Few foci on lungs. Testicles enlarged with several cheesy foci.

No. 2. Animal died from intestinal trouble, 28 days after inoculation with tubercle culture. No evidence of tubercular development.

No. 3. Died 80 days after injection. Intestinal trouble.

No. 4. Killed 133 days after injection. Animal fat and in good condition. No symptoms of tubercle.

No. 5. Killed 47 days after inoculation. No tubercle lesions.

No. 6. Died in 35 days. Slight enlargement of cutaneous lymphatics but no tuberculous foci.

No. 7. Died from bowel trouble 27 days after injection.

TABLE IV.—*Experiments on thermal death point of tubercle bacillus.*

Series II.—Origin of culture: Bovine (Th. Smith III).

Lab. No.	Time of exposure. (Min.)	Quantity injected. (c. c.)	Weight of Animal.		Period of incubation. (Days.)	Result.	Remarks.
			Initial. (Gms.)	Final. (Gms.)			
8......	10	2.4	515	460	56	—	No lesions of tuberculosis.
9......	10	1.6	469	578	82	—	No tuberculosis.
10.....	15	1.6	374	365	100	—	No tubercular lesions.
11......	15	1.6	516	344	79	—	Free from tubercular lesions.
12......	22	1.6	409	243	39	—	No tuberculosis.
13......	22	1.6	404	28.0	64	—	No symptoms of tuberculosis.

+ = tuberculosis; — = healthy.

DETAILS OF SERIES II.

Culture 34 days old when used. Salt suspensions made in usual way. Four cc. fresh milk mixed with one cc. of suspension for each time period. Minimum temperature of pasteurizer during heating 59.5° C., maximum 61° C. As culture used was of same origin as Series I, no control animal infected with unheated milk was used.

Post Mortem Notes.—No. 8 died 56 days after injection. Found stomach greatly distended with gas. Small intestine much inflamed. No tubercle lesions.

Nos. 9–13. No symptoms of tuberculosis in any case.

TABLE V.—*Experiments on thermal death point of tubercle bacillus.*

Series III.—Origin of culture: Bovine (Ravenel B).

Lab. No.	Time of exposure. (Min.)	Quantity injected (c. c.)	Weight of Animal. Initial. (Gms.)	Weight of Animal. Final. (Gms.)	Period of incubation. (Days.)	Result.	Remarks.
14......	0	1.6	768	483	17	+	Acute generalized tuberculosis.
15......	5	1.6	624	456	42	+	Disease well distributed.
16......	5	1.5	670	474	83	+	Similar to No. 15.
17......	10	1.6	651	690	86	—	No signs of tubercle.
18......	10	1.6	570	564	85	—	No signs of tubercle.

+ = tuberculosis; — = healthy.

DETAILS OF SERIES III.

Culture 27 days old, grown on dog's serum. Salt suspension made in usual way. To one cc. of this suspension added 3 cc. of fresh milk for each time period. Maximum temperature of apparatus during heating 60.5° C.; minimum 59.5° C. Took 7 minutes to heat tubes from 45° to 60° C. Control animal inoculated with unheated milk; also animals with milk heated for 5 and 10 minutes. Control pig No. 14 gave birth to one young, 12 days after infection.

Post mortem notes.—No. 14 (control) died in 17 days from acute generalized tuberculosis; nodules on peritoneum, omentum, liver. Lungs congested but apparently no tubercular foci.

No. 15. Chloroformed in 42 days. Cutaneous lymphatics of thigh enlarged, cheesy. Adhesions among intestines; mesenteric lymphatics enlarged, broken down in one case. One tubercle, 2mm. in diameter on spleen, grayish nodules on right lung; also several tubercular areas on liver. Thoroughly distributed case.

No. 16. Died in 83 days. Large abscess in lymphatics under skin. Liver badly affected, also spleen and mesenteric lymph glands. Nodules on pleura and both lungs. Disease well distributed.

Nos. 17 and 18. Killed in 86 and 85 days. Both well nourished; no symptoms of tubercle.

TABLE VI.—*Experiments on thermal death point of tubercle bacillus*

Series IV.—Origin of culture: Bovine (Th. Smith III).

Lab. No	Time of exposure. (Min.)	Quanity injected. (c. c.)	Weight of Animal. Initial. (Gms.)	Weight of Animal. Final. (Gms.)	Period of incubation. (Days.)	Result.	Remarks.
19......	0	1.5	602	448	13	+	Well marked case but confined to peritoneal cavity.
20......	5	1.6	546	508	108	+	Well developed but slow case.
21......	5	2.4	552	530	68	+	Disease well distributed in body cavity.
22......	10	1.5	515	670	117	—	One mesenteric lymphatic enlarged, soft in center.
23......	10	2.4	463	513	108	—	Cutaneous lymph glands enlarged but no caseation or suppuration.

+ = tuberculosis; — = healthy.

DETAILS OF SERIES IV.

Culture 27 days old, same origin as Series I and II. One cc. of salt suspension added to 3 cc. of fresh milk for each time period. Took one and three-fourths minutes to heat cultures from 45° to 60° C. Minimum temperature in pasteurizer 58.8°; maximum 60°.

Post mortem notes.—No. 19 died from generalized tuberculosis in 13 days. Tubercles in clavicular and inguinal cutaneous lymphatics. Intestines adherent to each other; small discrete tubercles. Spleen enlarged but no apparent tubercles. Lungs not affected.

No. 20. Chloroformed after 108 days. Intestines, spleen, liver and peritoneum affected. Lungs not affected but mediastinal lymphatic much enlarged. Disease slow in development.

No. 21. Chloroformed in 68 days. Large tubercle on abdominal wall at point of inoculation. Peritoneum and spleen studded with numerous tubercles. Numerous necrotic areas on liver.

No. 22. Chloroformed in 117 days. One mesenteric lymphatic somewhat enlarged, broken down on inside. Microscopical examination of tissue showed however that it was not tubercular.

No. 23. Chloroformed in 108 days. No symptoms of disease except an enlarged cutaneous lymphatic which was however not caseous or purulent.

TABLE VII.—*Experiments on thermal death point of tubercle bacillus.*

Series V.—Origin of culture: Bovine through horse (Ravenel C).

Lab. No.	Time of exposure. (Min.)	Quantity injected. (c. c.)	Weight of animal.		Period of incubation. (Days.)	Result.	Remarks.
			Initial. (Gms.)	Final. (Gms.)			
24......	0	1.4	546	382	19	+	Generalized in peritoneal cavity.
25......	10	2.2	455	544	89	—	No signs of tubercle.
26......	10	1.4	410	480	89	—	No signs of tubercle.
27......	15	2.3	350	412	89	—	No signs of tubercle.
28......	15	1.4	405	520	89	—	No signs of tubercle.
29......	20	2.8	323	414	89	—	No signs of tubercle.
30......	20	1.5	390	480	89	—	No signs of tubercle.

+ = tuberculosis; — = healthy.

DETAILS OF SERIES V.

Culture 18 days old, seventh generation, from a horse that had probably acquired the disease from a bovine source. Tubes for each time period loaded with 1.2 cc. of suspension of culture and 3 cc. of milk. Five minutes to heat from 45° to 60° C. Minimum temperature of pasteurizer 59.7° C.; maximum 60.4° C.

Post mortem notes.—No. 24 died in 19 days, severe case, generalized in peritoneal cavity.

Nos. 25–30. All healthy. Chloroformed after 89 days but no signs of tuberculosis in any of them.

SUMMARY OF SERIES I–V.

In order to permit of a closer comparison of the data secured in the different series, Fig. 21 is presented. From this it is evident that the results obtained from the inoculation experiments are surprisingly uniform.

In all cases the unheated milk (0 min.) that served as a control produced tuberculosis that invariably ran a rapid course, ending in death within a period of fifteen to nineteen days.

With the samples of milk subjected to the pasteurizing treatment, there is a sharp differentiation in the results of the animal inoculation. Without exception those cases where the exposure to the heat was only five minutes resulted in the production of tuberculosis, the majority of cases showing a generalization of the disease, which either terminated fatally or would probably have done so in a period ranging from two to four months.

SERIES.

TIME EXPOSURE	I.	II.	III.	IV.	V.
45 MIN.	— —				
40 "					
35 "					
30 "	— —				
25 "					
20 "		— —			— —
15 "	— —	— —			— —
10 "		— —	— —	— —	— —
5 "			+ +	+ +	
0 "	+		+	+	+

FIG. 21.—Diagram showing results of animal inoculations with tuberculous milk pasteurized at 140° F., under commercial conditions. + indicates development of tuberculosis; — animal remained healthy.

These results are in striking contrast with those obtained in the case where the time of exposure was for 10 minutes or longer. In every series the tissues were demonstrated to be entirely free from tuberculosis.

The conclusion from these series indicates that a temperature of 10 minutes at 60° C. (140° F.) is sufficient to destroy the vitality of the tubercle organism so completely that large doses inoculated in the most susceptible portion of a very susceptible animal (guinea pig) fail to produce any development of the disease,

while unheated samples of milk and those exposed to 60° C. (140° F.) for five minutes produced the disease without exception.

COMPARISON OF RESULTS WITH MILK PASTEURIZED IN A QUIESCENT AND AGITATED CONDITION.

In the scientific demonstration of the proper temperature point at which the tubercle bacillus would be killed recourse is had to heating the organism in thin walled test tubes filled with various liquids, the same being immersed in a water bath held at the desired temperature. Th. Smith[1] has previously shown that the results obtained with milk may differ considerably from what is found when the bacteria are heated in water, bouillon or solutions of various salts. When the bacilli were exposed under ordinary conditions in milk, they sometimes resisted the action of heat for a long time (over an hour), although the results obtained varied much. He was led to the view that this variation was caused by the formation of the "scalded skin" on the surface, which in some way protected the organisms enclosed so that they were able to resist the action of the heat for much longer periods of time. This view was further strengthened by the fact that when experiments were made with milk in sealed tubes (in which no surface pellicle could form), the thermal death point did not differ from the results obtained in other liquids.

This point is one of considerable practical importance for it shows that the efficiency of any pasteurizing treatment of milk depends in considerable degree on the conditions under which it is carried out.

It is the custom on the part of some to heat milk in an open vessel, either in bottles or in a vat that is more or less open to the air. Under such conditions the scalded pellicle can form very much more readily than it can where the milk is treated in a closed pasteurizer. Particularly is this true where the fluid is agitated, as under these conditions the scalding of the casein is much less likely to occur.

In order to test the relation of these two methods, Series VI and VII were made in which a comparison is made between that

[1] Journ. of Expt. Med., 1899, 4:217.

which has been pasteurized under commercial conditions in a Pott's machine, and also that heated in a quiescent condition in a water bath. In the latter case, the container was closed from direct contact with the air by means of a layer of absorbent cotton. The details of these experiments are as follows:

TABLE VIII.—*Experiments on thermal death point of tubercle bacillus where milk is heated in open and closed pasteurizers.*

Series VI.—Origin of culture: Bovine (Ravenel H).

Lab. No.	Manner of heating.	Time of exposure. (Min.)	Quantity injected. (c. c.)	Weight of Animal.		Period of incubation. (Days.)	Result.	Remarks.
				Initial. (Gms.)	Final. (Gms.)			
14....	Unheated......	0	1.6	768	483	17	+	
31....	Open bottles...	5	1.6 cream.	608	410	63	+	Generalized, severe.
32....	Open bottles...	5	1.5	469	313	62	+	Very severe.
15....	Closed apparatus.	5	1.6	624	456	42	+	Well distributed but few foci.
16....	Closed apparatus.	5	1.5	670	474	84	+	Well generalized, severe case.
33....	Open bottles...	10	1.6 cream.	710	570	86	+	Generalized case.
34....	Open bottles...	10	1.5	550	394	86	+	
17....	Closed apparatus.	10	1.6	651	630	86	—	No tubercular lesions.
18....	Closed apparatus.	10	1.6	570	564	85	—	No tubercular lesions.

+ = tuberculosis: — = healthy.

DETAILS OF SERIES VI.

Culture 27 days old. For details as to time of heating of agitated samples in Pott's pasteurizer see Series III, page, 159.

Samples heated in quiescent condition required six minutes to raise temperature from 45° to 60° C., maximum temperature during heating 60.75° C., minimum 60° C.

Post mortem notes.—Autopsies of animals inoculated with milk treated in Pott's pasteurizer (Nos. 15–18) are detailed on page 159. Those injected with milk heated in water bath are as follows:

No. 31. Inoculated with undisturbed cream on surface of milk. Killed in 63 days. Cutaneous lymphatics suppurating. Numerous discrete tubercles on peritoneum, omentum. Liver entirely covered with necrotic areas. Spleen enlarged and affected. Lungs partially consolidated.

No. 32. Inoculated with remaining portion of milk. Lymphatics of axilla and inguinal region affected; also those of mesentery. Spleen enlarged, shows numerous nodular foci. Liver badly affected. Pleura and lungs completely studded with grayish tubercles. Evidently the differentiation of milk into the cream and remaining layers made no difference in virulence.

No. 33. Inoculated with cream. Disease distributed in peritoneal cavity but not severe except in spleen and liver. Lungs slightly affected, upper lobe left lung severe.

No. 34. Lesions very similar in distribution and extent to No. 33.

TABLE IX.—*Experiments on thermal death point of tubercle bacillus where milk is heated in open and closed pasteurizers.*

Series VII.—Origin: Bovine (Th. Smith III).

Lab. No.	Manner of heating.	Time of exposure. (Min.)	Quantity injected. (c. c.)	Weight of Animal.		Period of incubation. (Days.)	Result.	Remarks.
				Initial. (Gms.)	Final. (Gms.)			
19....	Unheated....	0	1.5	602	448	13	+	Confined mainly to peritoneal cavity.
35....	Open bottle..	10	1.6	460	324	42	+	Severe in peritoneal cavity.
36....	Open bottle..	10	2.1	630	610	108	+	Generalized but not severe.
20....	Closed apparatus.	5	1.6	546	508	108	+	Slow but well developed.
21....	Closed apparatus.	5	2.4	552	530	68	+	Peritoneal cavity affected.
37....	Open bottle..	15	1.4	504	390	49	+	Relatively slight.
38....	Open bottle..	15	2.7	483	310	49	+	Advanced generalized case.
22....	Closed apparatus.	10	1.5	515	670	117	—	One mesenteric lymph gland broken down.
23....	Closed apparatus.	10	2.4	463	513	108	—	Cutaneous lymph gland enlarged but not caseous or suppurating.

+ = tuberculosis; — = healthy.

DETAILS OF SERIES VII.

Culture 27 days old when used. See Series IV for details of heating agitated samples. Remaining samples heated in water bath. Took 4½ minutes to raise milk in tubes from 45° to 60° C. Held at 60° C., for 5 and 10 minute periods.

Post mortem notes.—For autopsies of Nos. 19–23 see page 160, Series IV.

No. 35 died in 42 days. Several tubercles on peritoneum and mesentery. Spleen much enlarged, studded with tiny nodules. Liver badly affected. Few foci in lungs.

No. 36. Few tubercles on peritoneum. Scattered nodules in liver. Spleen enlarged. Lungs affected, pleural face of diaphragm.

No. 37. Killed in 49 days, numerous miliary nodules on peritoneum. Mesenteric lymphatics enlarged and frequently tuberculous. Spleen badly affected.

No. 38. Tubercular foci on abdominal wall, mesenteric lymph glands, omentum, spleen, liver and lungs.

In order to permit of a more direct comparison of the results obtained where the organism was exposed in milk that was open to and also closed from access of air the data of the two preceding series as to the results of the inoculation of animals is presented in Figure 22.

SERIES.

TIME EXPOSURE	VI.		VII.	
	POTT'S	BOTTLE	POTT'S	BOTTLE
20 MIN.				
15 "				+ +
10 "	— —	+ +	— —	+ +
5 "	+ +	+ +	+ +	
0 "	+	+	+	+

FIG. 22.—Diagram showing comparative results of animal inoculations made with milk heated to 140° F., in a closed commercial pasteurizer, and also in open vessel. + indicates development of tuberculosis; — animal remained healthy.

It is evident from the above that the results obtained in each series by either method of exposure are confirmatory of each

other; but that the results of one method differ sharply from those of the other. Where the milk was exposed in a quiescent condition as in a glass tube or bottle, the tubercle bacilli were more resistant than where the milk was in a closed receiver and agitated. While all tubercular organisms were destroyed in the commercial pasteurizer in ten minutes, neither an exposure for this period nor for fifteen minutes sufficed to destroy the same lot of organisms when the milk was treated in a quiescent condition at the same temperature in vessels to which the air had more access.

Whether this more prolonged resistance to the action of heat when kept in a quiescent condition is due to the formation of the thin film or "skin" on the milk or not is another question. When milk was carefully heated in a water bath at 60° C., signs of a thin "skin" could be detected in about 20 minutes. In all probability these flocculent patches would begin to make their actual appearance before they could be recognized with the unaided eye, and it seems probable that they protect in some way the living bacilli so that they are not acted on by the heat as readily as when the conditions do not favor the formation of such films.

The results of these tests confirm the data reported by Smith, and show that when milk is used as a menstruum that the thermal death point of the tubercle bacillus is subject to some fluctuation, depending on whether the fluid in which the organism is treated is exposed under conditions that will permit of the formation of the "scalded layer." Unquestionably this relation is one of importance in commercial pasteurization of milk and cream; for, according to some certain methods now in use, it is customary to heat the product after it has been placed in bottles. In such cases, unless the bottles are closed perfectly tight, the same causes that operate in test tubes closed with absorbent cotton plugs would also be effective where milk was heated in a quiescent condition after it had been bottled. Fortunately, however, the treatment of milk on a large scale for the purpose of preserving it is done in the main in apparatus that requires the milk to be kept in motion and under such conditions the milk is in a receiver that is closed from the air. Where pasteurized in bottles for individual use, as in the family, it will be necessary

to tightly seal bottles during the heating to insure complete destruction of pathogenic organisms within a brief period of exposure.

COMPARISON OF RESULTS OBTAINED UNDER LABORATORY (SMITH) AND COMMERCIAL CONDITIONS.

In order to compare the results obtained in this investigation under commercial conditions with those of Smith which were performed under laboratory conditions, the following abstract of his results is presented. In this, reference need only be made to those results of his which were obtained in the experiments made with milk sealed in glass tubes.

TABLE X.—*Results of animal inoculations made with tuberculous milk heated at 60° C. for varying periods of time (Th. Smith).*

CULTURE NO.	PERIOD OF EXPOSURE (MINUTES).						
	5	10	15	30	45	60	75
IV	....	....	—	—	—	—	—
VI	....	....	+	—	—	—	—
III	+	+	—	—	—	—	....

+ tuberculosis produced. — no disease.

While there is some variation in his figures, in only one instance did he find that the organism could withstand an exposure of fifteen minutes. In the experiments made with the other liquids as bouillon, water, and salt solution, only one other instance was observed where the organism survived a net exposure of an equal period of time. Our experiments show no case where the vitality of the organism was retained after an exposure of ten minutes so there can be no doubt but that an exposure of from fifteen to twenty minutes would certainly destroy all organisms of this class.

In commercial pasteurizing it should be borne in mind that the results of the experiments here reported (both Smith's and our own) are for net exposures, i. e., the period of time during which the organisms were heated at a temperature of 60° C. (140° F.). This would not include the interval necessary to raise the temperature of the milk in the pasteurizer from normal

temperatures to the proper pasteurizing point, but as the time limit for efficient pasteurizing is always computed from the time that the milk reaches the proper killing temperature no change in method of computing time is necessary.

GENERAL SUMMARY.

The results of the recent experiments of Theobald Smith as to the thermal death point of the tubercle bacillus of bovine origin when exposed in milk vary so much from the standards heretofore adopted that it is exceedingly desirable that a retest of this work be made under commercial conditions, as the question is one of great practical importance in the pasteurization of milk and cream.

The standards previously used in pasteurization have been 150 to 155° F. (65–68° C.), for 15 to 20 minutes. Under these conditions the consistency of milk is materially changed. The cream does not rise readily on milk so treated, and the consistency or "body" of cream itself is much lessened. If the exposure is made at the temperature of 140° F. (60° C.) or below, this diminution in consistency does not occur. In fact milk or cream heated no higher than this cannot be distinguished from the normal product.

If it is possible to effectually destroy the tubercle bacillus at this temperature by an exposure for a brief period of time, a new standard for pasteurization may be made that will enable one to overcome the only objection that has ever been raised against the use of this product.

The results of the foregoing experiments are as follows:—

1) An exposure of tuberculous milk in a tightly closed commercial pasteurizer for a period of ten minutes destroyed in every case the tubercle bacillus as determined by the inoculation of such heated milk into susceptible animals like guinea pigs.

2) Where milk was exposed under conditions that would enable a surface pellicle or membrane to form on the surface, the tubercle organism is able to resist the action of heat at 140° F. (60° C.) for considerably longer periods of time.

3) Efficient pasteurization can be more readily accomplished in a closed receptacle such as is most frequently used in the com-

mercial treatment of milk than where the milk is heated in open bottles or open vats.

4) It is recommended in order to thoroughly pasteurize milk so as to destroy any tubercle bacilli which it may contain, without in any way injuring its creaming properties or consistency, to heat the same in closed pasteurizers for a period of not less than twenty minutes at 140° F. (60° C.).

Under these conditions one may be certain that disease bacteria such as the tubercle bacillus will be destroyed without the milk or cream being injured in any way. For over a year this new standard has been in constant use in the University Creamery and the results from a purely practical point of view reported last year by Farrington and Russell,[1] have been abundantly confirmed.

[1] 16 Rept. Wis. Agr. Expt. Station, 1899, p. 129.

OUTBREAK OF ANTHRAX FEVER TRACEABLE TO TANNERY REFUSE.

H. L. RUSSELL.

During July and August, 1899, an outbreak of some contagious disease occurred among the stock on several farms on the Black River, below Medford, Taylor County, Wis. The matter was not investigated at the time and it was not until November of the same year that the Health Officer of the town, Dr. Eugene LeSage, sent samples of tissue from a horse that had just died on the farm of a man who had previously lost some stock.

From the samples (stomach, liver and spleen) a bacteriological examination was made with the following results:

Cover glass preparations prepared directly from the blood showed numerous chains of large bacilli that were apparently bacilli of anthrax fever. Cultures were made from the blood and from these the characteristic organism of anthrax was separated. The virulence of the disease germ was tested by subcutaneous inoculations of broth cultures into a guinea pig. In 28 hours the pig died and a post mortem examination showed the characteristic enlargement of the spleen, the blood appearing very dark and not coagulating. Microscopic examination of blood and cultures from the inoculated pig left no room for doubt but that the disease from which the horse died was that of anthrax.

Inasmuch as anthrax does not normally occur in this state, it was important to determine the distribution of the disease, and so find out if possible the way in which the infectious organism causing the same had been established. While anthrax is naturally enzoötic in many foreign countries, i. e., it is present continuously as an animal disease, still in this country it has not

been able to establish itself permanently, except in a few localities. It has been introduced, however, temporarily in quite a large number of cases and there is no good reason to believe but that had it not been for stringent precautions taken to prevent it from gaining a firm foothold, the disease would adjust itself to our conditions so that it would be a permanent menace to our stock interests.

HISTORY OF OUTBREAK.

Through the kindness of Dr. Eugene LeSage of Medford, a partial history of the outbreak of the preceding summer has been secured. This, with the further data collected by me on several visits to the region, is herewith presented to show the extent and distribution of the disease.

The disease is confined to the banks of the Black River below the city of Medford. Although several small tributaries join this stream (see map) the trouble has not appeared as yet on any of the same.

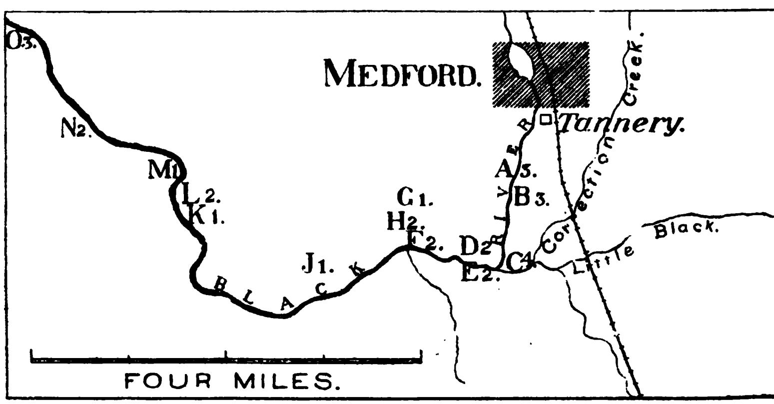

FIG. 23.—Map showing distribution of anthrax fever cases and relation of same to river pollution. Individual farms indicated by letters; number of anthrax cases on said farms by numbers.

For the distance of about 10 miles down stream, farmers whose lands were contiguous to the river have lost in all this last year about 30 head of stock (horses and cattle). The losses have been widely distributed, occurring on at least fourteen farms, the individual loss ranging from one to four animals. Actual losses

for past season are indicated on the respective farms on the map. When one considers in addition to the widespread occurrence of the disease that the outbreak extended nearly to the limits of the present settled region and that the losses were sometimes all or nearly all of the stock owned by the farmers, the severity of the same is apparent. It was impossible to get any very satisfactory data as to the symptoms of the disease. Most of the animals were reported as sick but 24–36 hours. Generally a high fever was noted, and sometimes blood was observed issuing from the natural openings (mouth and rectum). In some instances the farmers opened the carcasses, and the enlarged spleen characteristic of anthrax was the most conspicuous condition. While the symptoms and post mortem data are too unsatisfactory on which to place much reliance, one other factor practically settles the case, and that is the artificial inoculation of no less than five persons. These infections were caused by persons skinning animals to save the hides, and in all cases carbuncles were produced on exposed parts of body (hands, arms, etc.). In some cases where treatment was delayed general infection followed, nearly resulting in death in some instances. The diagnosis of physicians having charge of these cases was anthrax.

Inquiry among stock owners showed undoubtedly that the disease was produced either by drinking river water or grazing on lowland meadows. In several instances animals kept from the river or meadow lands but fed on hay taken from such meadows acquired the disease, showing that the grass was contaminated with the spores of the disease germ.

ORIGIN OF THE DISEASE ORGANISM.

The distribution of the disease along the river bottom lands leaves no doubt as to the fact that the river has been the means of spreading the same. But how did the disease germ originally find its way into the river? Just below the city of Medford there is located a tannery and the waste waters from this are discharged into a canal that empties into the Black river. The refuse waters from the tannery contain in addition to the wash water, water from the soak vats, more or less solid material as

hair, particles of flesh, hide, etc. These are discharged with liquid wastes and although provision is made by screening to remove the coarser particles, some of this coarse refuse and all of the liquid wastes finds its way down stream. In the spring of the year when the river is high and the low meadow lands are inundated, more or less of this material is floated back from the main current there to remain as the stream subsides. Particles of hair and flesh are reported as having been frequently found in the meadow grass.

The disease of anthrax occurs most commonly in cattle and sheep, although other domesticated animals are by no means exempt from it. It is a blood affection and every drop of blood from the animal contains the living organisms that are capable of propagating themselves if placed under favorable conditions. While the germ in the living animal is in the vegetating condition and is incapable of long retaining its vitality in competition with putrefactive bacteria, it forms spores very readily when exposed to the air, and when these are once produced, the resistance of the disease germ is enormously increased as anthrax spores in a dried condition can retain their vitality for years. It therefore follows that hides from infected animals always contain these spores as the skins are inevitably covered with some blood. If, therefore, the tanneries should use infected hides, all of the rest of the conditions necessary for the transference of the disease germs from originally infected animals to healthy stock are present.

As the disease cannot originate in and of itself, but must come from some pre-existing cause, and as it is not naturally established in any contiguous portion of the county, it is practically certain, in view of all the circumstances surrounding the case that the infection was spread by the use of diseased hides. But from whence came these hides? An inquiry made of the tannery manager elicited the fact that the bulk of the hides tanned are imported from South America (Buenos Ayres and Montivideo) but that during the past year possibly 25% of the hides treated came from China. It has long been known that this disease is thoroughly established in many regions of Asia, Europe, and to a lesser extent in Africa and portions of South America, and

that practically hides of Asiatic origin frequently cause outbreaks of anthrax in the vicinity of tanneries.

REPORTS OF ANTHRAX OUTBREAKS OCCURRING IN CLOSE RELATION WITH TANNERIES.

That the causal relation between this disease and the tannery above referred to is by no means uncommon is evident from the reported outbreaks of anthrax that have been noted from time to time in other portions of the United States. For the past eight years anthrax has broken out at various places in Delaware[1] along the banks of the Delaware river and its tributaries. These outbreaks have had at least five foci from which the infection primarily originated. In one case it was traced to the sewage of one of the morocco shops in Wilmington where South American goat skins were being handled. In the remaining four outbreaks the cause has been due to the floating ashore of disease virus. Presumably this has come from carcasses of animals that have been thrown into the river, as such have been observed in the river from time to time, and as it is known that the disease prevailed on the New Jersey shore farther up stream. According to Professor Neale of the Delaware Experiment Station there were in 1896, twenty-five morocco shops in Philadelphia that worked up 100,000 goat skins daily, and fourteen such shops in Wilmington where 25,000 skins a day were handled. Anthrax has quite frequently developed among the workmen in these shops, showing that the hides are at times infected and it is more than probable that the contamination of the Delaware river is attributable to this source.

Ravenel[2] has reported outbreaks in three different localities in Pennsylvania where the disease occurred either among workmen in tanneries or cattle pastured on meadows watered by streams carrying tannery refuse. These tanneries were all under the control of a single company and at each place hides had been received from China.

Localized outbreaks have also occurred in at least ten or twelve other states. In a number of cases the inception of the disease

[1] Delaware Expt. Station 7th, 8th and 9th Annual Reports, 1895-97.

[2] Philadelphia Medical Journal, April 22, 1899.

has been associated with tanneries. Rembold[1] cites nine cases of human infection in a small town in Germany in four years. All but one were operatives in tanneries. In the same district in 12 years, anthrax occurred on 23 different farms, in all but six of which pollution with tannery refuse was directly or indirectly possible. On "wild hides" imported from China he was able to find *Bacillus anthracis*. Confirmatory cases of the relation of tanneries to the spread of the disease might be increased almost indefinitely, if such were necessary.

It would seem then that the tanning of hides from infected regions is a menace not only to animal industry but to public health as well, for in the aggregate, the number of persons, principally tannery operatives, who contract anthrax (malignant pustule or carbuncle) is by no means inconsiderable. This question is one of considerable importance in this state as in other states containing forests from which tan bark is to be had in merchantable quantities. Fortunately the tanneries of Wisconsin, of which there are a goodly number, are situated in lake shore towns where the refuse is emptied almost directly into the lake, or are located in the north central and northern part of the state where the country has not yet been settled to any great extent. The danger at present then to the agricultural interests of the state is much reduced on account of this condition. As the northern regions become settled and stock is introduced more and more, the danger from streams receiving tannery refuse will undoubtedly be increased. It may be noted in this connection that in the present outbreak, the disease was traced down the Black river practically to the border of the already settled regions.

The outbreak of anthrax among the tannery operatives at Mellen, Ashland County, in the summer of 1899, also indicates that diseased hides were handled in this tannery. If the region contiguous to the drainage stream into which this tannery refuse flowed had been stocked with cattle and other animals, undoubtedly another animal outbreak would have been chronicled at this place. Under existing circumstances the only susceptible hosts (human beings) were affected.

[1] Zeit. f. Hygiene, 1888, 4:498.

HOW CAN THE DANGER BE MINIMIZED OR ELIMINATED?

Without entering into the legal phase of this question, it is evident that steps should be taken to lessen the danger from this disease in relation to tanneries: first to human beings; and second, to the agricultural interests exposed to infection.

Anthrax is not indigenous to this country; consequently, the use of American hides for tanning purposes is not a source of danger. Neither is it likely that the hides from all foreign countries are liable to be diseased. So far where epizoötics have occurred, they have generally been traced to Chinese hides, although the disease in England has also been connected with the use of South American skins. At the present time there are United States regulations that permit the President to place an embargo on the importation of hides from neat cattle coming from known infected districts, but it has been considered impossible on the part of the Government authorities to enforce this law, as there exists at present no practicable means, whereby it is possible to determine whether any consignment of hides intended for shipment is infected or not.

Can the hides be efficiently disinfected?—Barring the absolute exclusion of all suspected hides, another course to pursue would be the disinfection of the same by some process that would destroy the spores of this organism without altering the character of the hides for tanning. The germ of this disease can be readily killed by the use of steam and a large number of strong disinfectants as mercury, carbolic acid, etc., but these practically destroy the value of the hide, and are therefore useless for the desired purpose.

Experiments have been made with various substances as sulfur and hydrofluoric acid[1] but with poor success. Formalin has been recommended as a suitable agent by Eitner, but from the marked action of formaldehyde on albuminoid matter, it seemed probable that the hides would be injured if any considerable quantities of this disinfectant were used. In order, however, to test this matter, a series of experiments were outlined, and

[1] Leather Trades' Review, Aug. 8, 1399.

were executed under my direction by my assistant, Mr. E. G. Hastings.

Preliminary to the tanning process, the hides as received are allowed to macerate for several days in "soak vats" filled with water. This softens the hide and loosens the hair so that when subjected to the fermentative "sweating" process, the hair and adherent flesh readily slough off. As the hides are allowed to remain in these soak vats from four to ten days, depending upon the temperature, it was thought that this stage would offer the best opportunity for the application of the disinfectant. In disinfecting at this stage, the tannery operatives would also be protected, for in the great majority of cases, "hide poisoning" or anthrax infection in human beings occurs among the operatives who clean off the remnants of flesh and hair after the hide has passed through the sweating process.

As formaldehyde renders albuminous bodies insoluble, it would be necessary in any event to use the most dilute solution possible. Under such circumstances the time of exposure must be considerably increased in order that the disinfection be efficient.

EXPERIMENTS ON TREATMENT OF ANTHRAX HIDES WITH FORMALDEHYDE SOLUTIONS.

E. G. HASTINGS.

Experimental methods.—Pieces of the dry hide were infected with anthrax spores by immersing them in a suspension of a sporebearing culture. The pieces were air-dried at 98° F., and then placed in solutions of formaldehyde of various strengths. At intervals pieces of the hide were removed, immersed in sterile water and shaken thoroughly to loosen the adherent spores. This suspension was then heated to 175° – 185° F., for ten minutes to kill the putrefactive forms present in a vegetating condition. Cultures on agar plates were then made with varying quantities of the water, and these incubated at blood heat.

From experiments made by others the concentration of formaldehyde that will destroy anthrax spores has been determined as follows: According to the researches of Stahl, E. von Ermengen and Sugg[1], anthrax spores are killed in one hour by a 1:1000

[1] Lafar, Technical Mycology, p. 115.

solution, and 1:750 solution proved fatal in a quarter of an hour. But in these experiments the germ alone was exposed to the chemical action of the disinfectant, and it by no means follows that results so obtained would apply where the exposure was made in the presence of large quantities of albuminous matter as with hides. The following table gives the results obtained where the infected hides were exposed to the influence of the disinfecting solution for varying periods of time.

TABLE I.—*Effect of formaldehyde on anthrax spores.*

TIME OF EXPOSURE.	STRENGTH OF SOLUTIONS OF FORMALDEHYDE.					
	1:500.	1:1000.	1:2500.	1:5000.	1:10000.	Control.
0 days	....	....	....	....	....	+
1 day	−	+	+	+	+	+
4 days	−	+	+	+	+	+
8 days	−	−	+	+	+	+
11 days	−	−	+	+	+	+

+ Colonies of anthrax. — No colonies of anthrax.

At the end of the experiment, anthrax spores capable of development were still present on the hide immersed in solutions containing 1:2500, 1:5000 and 1:10000 parts of formaldehyde, but considerable disinfecting action had occurred, as was shown by the decrease in the number of colonies found on the plates, although as the time of exposure was lengthened, larger quantities of material were used for inoculating the plates. These results were confirmed by a second test.

Where exposure was continued for some days the disinfectant generally diminished in strength owing to its action on the albuminoids of the hide. Tests for formaldehyde made at different intervals according to Deniges method[1] gave the following results:

TABLE II.— *Number of days after which no formaldehyde could be detected in different solutions.*

1:2500	1:5000	1:10000
12	10	8

In these experiments the ratio between the volume of disinfecting solution and the amount of hide was much greater than

[1] Analyst, 1896, 21:285.

would be practicable under commercial conditions, so that the disappearance of the disinfectant in these proportions would be much more rapid in tanning practice than here indicated.

ACTION OF FORMALDEHYDE ON HIDES.

In order to determine whether the action of formaldehyde on the hide would interfere with the successful tanning of the same, pieces were placed in solutions containing varying quantities of the disinfectant. After an exposure to the same for six days, they were removed and sent to the tannery to be subjected to the sweating process. The report from the tanner was as follows:

Samples immersed in solutions containing 1:500 and 1:1000 remained firm, and the hair did not "sweat off." Pieces exposed to solutions containing 1:2000, 1:5000 and 1:10000 were fairly well softened and sweat off to some extent, but not as thoroughly as they should. It is evident from the above that formaldehyde injures the tanning of the hide, as it coagulates the albuminoids in the skin and so prevents the ready removal of adherent flesh and hair. Its chemical union with these substances also lessens materially its disinfecting power and thereby renders it of little worth as an agent in destroying the disease germs adherent to hides.

The foregoing results indicate that formaldehyde does not offer much help to the tanner in the treatment of hides infected with anthrax. At the present time there appears to be no method of efficient disinfection that can be applied previous to the tanning process without injury to the hides.

The only recourse then, so far as the introduction of diseased hides is concerned, is to use all possible care with material imported from regions known to be infected with this disease. In this respect China hides have the worst reputation, as a very considerable number of outbreaks have occurred where skins from this region have been used.

So far as danger to operatives is concerned it seems then that no treatment can be given that will eliminate the possibility of infection of human beings. As infection in these cases is generally acquired through cuts or wounds on the hands and other exposed portions of the body, it is necessary to guard against this danger as much as possible by antiseptic treatment. Managers of tanneries should see that workmen do not neglect

any slight cuts or abrasions of the skin, but the same should be thoroughly disinfected by mercuric bichloride, carbolic acid, or some other well known disinfectant. Under ordinary conditions, man is not as susceptible to anthrax as the lower animals, and generally infection remains localized at point of introduction, producing the so-called malignant pustule or carbuncle. If the initial infection is neglected, a more general septicaemia (blood poisoning) may occur, which not infrequently terminates fatally. It is said by tanners that old operatives often become resistant to infection. This is undoubtedly due to a state of artificial immunity conferred by previous inoculations through invasion of the skin.

Although at the present time there is no recognized method of treating the hides before they are tanned, so as to destroy the organisms of this disease, yet this does not preclude the treatment of the tannery refuse after the waste material has been removed from the hide. Particles of hide, hair, and flesh, together with a considerable volume of wash water make up this refuse and naturally the spores of the disease germ are to be found on the solid material as well as in the water. From the distribution of the disease it seems probable that the solid refuse is more often concerned with the spread of the disease than the wash water; for the disease has been more frequently traced to inundated lands where the accumulation of such refuse on the soil would give exceptional facilities for the retention of these organisms. According to the experience of some of the farmers affected last season, it seems that animals were not affected at first when turned into low land meadows. As the season advanced, and the herbage consequently became shorter, forcing the stock to graze closer to the soil and to seek the lower portions of the pastures where the grass was more luxuriant, horses and cattle began to acquire the infection. In some cases this happened on meadows subject to inundation but not contiguous to the river, indicating very conclusively that the diseased material was deposited during high water. Again in some cases the disease was produced by feeding stock on hay gathered from these low meadows. The quantity of refuse, liquid as well as solid, is not so large but that it might be treated in a way so as to destroy

its infectious properties, by cremation of the solid matter and chemical disinfection of liquids.

WHAT CAN THE FARMER DO TO AVOID CONTAGION?

The stock owner is not entirely without means at his disposal to prevent his domesticated animals from acquiring the disease. There are two courses open to him. One which enables him to prevent his animals from acquiring the disease by rendering them insusceptible or immune, by virtue of preventive vaccination; the other to prevent the disease by quarantining affected areas.

When it becomes apparent that any piece of ground is infected, no domesticated animals should be allowed to graze on the same unless they have been previously vaccinated by means of the method mentioned below. Under no circumstances should the animal be skinned where the cause of death is anthrax, as in this process the blood, containing as it does millions of organisms, cannot be prevented from staining the soil. When these organisms come in contact with the air, they form the resistant spores which enables the germ to withstand drying almost indefinitely, and consequently, if the soil is once polluted, contagion may arise from this place.

In disposing of anthrax carcasses, they should never be thrown into the river, as has been done by some farmers in this outbreak. The only safe way is to bury them deeply or burn them unopened so as to destroy all contagious matter.

In some cases part of the pastures may be utilized by fencing off those areas that are most readily overflowed. Burning such marshes in the spring will also be helpful in destroying any possible disease germs. Hay should not be utilized from known infected localitites, for the disease organism retains its vitality on such fodder, and is able to infect animals which afterwards consume such, a condition that occurred on at least one farm in this outbreak.

Much can be done to prevent the spread of the disease by careful treatment of affected lands.

Relative to the use of protective measures, it may be said that the Pasteur method of vaccination is an efficient treatment in

the case of this disease. This method of vaccinating animals exposed to the contagion has been very successfully used in France and Austria, where the disease is widely spread and thoroughly established. It consists of the inoculation of stock with a vaccine virus prepared from cultures of the anthrax bacillus. This virus is artificially weakened to such an extent that it produces a very mild fever in the animal, which protects the same should infection with the more virulent organism occur later.

Animals protected in this way may be allowed to graze upon affected meadows with comparative safety. This method has been used successfully by the Delaware Experiment Station. Prof. F. D. Chester writes me: "We have vaccinated about 1,500 cattle and have only had four deaths among these animals, while in the same infected territory there have been in the same period about 150 deaths among unvaccinated cattle."

CONCLUSION.

Anthrax is not indigenous to this state, but during the past year a severe outbreak occurred in the vicinity of Medford that was limited to the banks of the Black river. The virus of the disease undoubtedly came from tannery refuse and was in all probability due to the use of "murrain" or infected hides imported from China. It seems quite probable that the lowland meadows were infected by inundation during high water, at which time particles of diseased hide and hair were deposited on the surface of the ground. About 30 cattle and horses died during the last season and several human beings contracted the disease in attempting to save the hides of affected animals.

No treatment is known that will enable tanneries to disinfect hides before subjecting the same to the tanning process. Experiments made with formaldehyde show that solutions sufficiently strong to kill anthrax spores injure the hides. It would be possible for tanneries to disinfect the refuse by chemical treatment and thus render it innocuous.

Farmers living on the banks of this stream should take precautions to prevent the spread of the disease. This can be done by vaccinating stock against anthrax by means of the Pasteur method, or by quarantining the stock against direct access to the

river or the inundated pasture lands. Hay from affected lands should not be used.

This relation of tanneries to the dissemination of the disease is one of the most common ways in which the disease is established in new regions. Fortunately most Wisconsin tanneries are located either in large cities where the refuse is discharged into the city's sewage, and little or no opportunity occurs for the infecting of agricultural lands, or they are located in sparsely settled or uninhabited regions in the northern part of the state where the stock interests have not yet been developed. With the settlement of these regions and the introduction of stock, this question will become more and more important.

INFLUENCE OF THE RIGHT AMOUNT AND RIGHT DISTRIBUTION OF WATER IN CROP PRODUCTION.

F. H. KING.

The present year has been relatively a poor one for hay and small grains but unusually good for corn at the Station.

Rainfall of Madison during the growing season of 1900.

Date.	Rainfall in inches.	Rainfall 10 day periods.	Date.	Rainfall in inches.	Rainfall 10 day periods.	Date.	Rainfall in inches.	Rainfall 10 day periods.
April 11...	.11	....	June 14...	.10	1.07	July 24...	.18	....
12...	.02	....	21...	.85	....	25...	.05	1.45
13...	.02	....	22...	.51	....	Aug. 2...	.10	.10
15...	.05	....	23...	.01	1.37	12...	.38	....
16...	.07	....	July 1...	.04	....	13...	.07	....
17...	.79	....	2...	.75	....	14...	.06	....
18...	.26	....	3...	1.01	....	15...	.18	....
19...	.05	1.33	4...	.23	....	16...	.06	.75
May 4...	.15	....	6...	.25	....	19...	.04	....
8...	.66	....	7...	.36	....	20...	.08	....
9...	.10	.91	8...	.10	2.74	23...	1.32	....
15...	.08	....	10...	.24	....	24...	.21	....
16...	.74	.82	11...	.04	....	25...	.11	1.74
28...	.13	.13	14...	.30	....	Sept. 2...	.09	.09
June 2...	.40	....	15...	.58	....	11...	.49	....
7...	.29	....	16...	.33	....	15...	.13	.62
8...	.07	.76	17...	1.41	....	18...	.06	....
10...	.53	....	18...	.02	2.92	19...	.67	....
11...	.42	....	20...	.63	....	20...	.06	....
13...	.02	....	21...	.59	....			

Comparing the rainfall of this with the past two years the results stand as below:

Date.	April.			May.			June.		
	1-10	10-20	20-30	30-10	10-20	20-30	30-9	9-19	19-29
1898.............	.21	1.61	.56	1.41	2.55	.75	.11	1.49	2.87
1899.............	.19	.03	2.54	1.00	1 01	2.50	1.25	1.16	.45
1900.............	.00	1.33	.00	.91	.82	.13	.76	1.07	1.37

Date.	July.			August.			September.		
	29-9	9-19	19-29	29-8	8-18	18-28	28-7	7-17	17-27
1898.............	.29	2.55	.10	.95	1.20	.44	1.02	.44	.04
1899.............	2.54	.48	.24	2.16	.37	1.01	.46	.30	2.65
1900.............	2 74	2.92	1 45	.10	.75	1.74	.09	.02	....

It will be seen that the rainfall this year has been below the average in the early part of the season but heavier than normal during the month of July.

The smaller rainfall in the spring made a short first crop of hay and less yields of small grains, but it favored the development of plant food in the soil for corn and lessened the leaching of it away and the heavy crop of corn has been due (1) to the early development of nitrates in the soil, (2) to the excellent distribution and abundance of rain during July, and (3) to the high temperature of July and August.

THE YIELD OF HAY.

Clover killed badly last winter but not so completely as the year before and this has lessened our yield of hay. Being able to irrigate the plots in clover and alfalfa the deficiency of rain in May and June did not reduce the crop and the yields are given below:

No. of plots.	2	4	7	8
1st crop, in tons, per acre	1.579	2.600	1.970	1.640
2d crop, in tons, per acre	1.854	1.094	2.826	1.864
3d crop, in tons, per acre	.670	.....	.981	1.498
4th crop, in tons, per acre	.....	.....	.....	.742
Total, in tons, per acre	4.105	3.694	5.777	5.744

The yield of hay per acre for the first and second crops for the past five years has averaged.

For 1896	4.044 tons per acre of hay containing 15 per cent. moisture.
For 1897	4.434 tons per acre of hay containing 15 per cent. moisture.
For 1898	4.031 tons per acre of hay containing 15 per cent. moisture.
For 1899	4.242 tons per acre of hay containing 15 per cent. moisture.
For 1900	4.232 tons per acre of hay containing 15 per cent. moisture.

THE YIELDS OF CORN.

The yield of water-free dry matter in corn on plot 1 this year was an average of 11,208 lbs., carrying 3,139 lbs. of water-free ear corn equal to a little more than 51 bushels per acre.

On plot 3 the yield was 11,279 lbs. water-free matter per acre and the yield of ear corn was 48.3 bushels. On these two plots the corn was planted in rows three feet apart and in hills 18 inches apart with three to five stalks in a hill. These plots were in potatoes last year and manured then.

The plot which was fallow last year gave this season a mean yield of 12,582 lbs. of water-free matter per acre carrying 88.9 bushels of corn. One of the sub-plots in this trial yielded 121 bushels of corn and 14,811 lbs. of water-free matter per acre.

The yield of corn on plot 9 has been a little larger this year than in 1899 or '98. This is probably due in part to the better season, but perhaps chiefly to the fact that we used only one-half the amount of seed, planting in hills 30 inches each way. The yields for the seven years of this intensive continuous cropping are given in the table below:

Year.	Kind of corn.	Not irrigated.		Irrigated.		Difference in water used.	Difference in yield.
		Inches of water.	Pounds of dry matter.	Inches of water.	Pounds of dry matter.	Inches.	Pounds of dry matter.
1894......	Flint.......	8.15	7,916	16.76	11,080	8.61	3,164
	Dent........		7,426		9,625		2,199
1895......	Flint.......	4.48	2,458	31.08	10,048	26.60	7,590
	Dent........		3,144		11,125		7,981
1896......	Flint.......	15.02	8,129	27.07	10,320	12.03	2,191
	Dent........		8,450		10,280		1,830
1897......	Flint.......	10.66	6,766	16.36	8,571	5.70	1,805
	Dent........		6,853		8,438		1,585
1898	Flint.......	11.02	7,558	16.72	6,882	5.7	—676
	Dent........		7,581		7,330		—251
1899......	Flint.......	12.12	6,607	15.54	6,480	3.42	—127
	Dent........		6,913		7,431		518
1900......	Flint.......	13.12	7,445	15.69	7,585	2.57	140
	Dent........		8,450		8,473		23

It will be seen that the unirrigated yield has been as large for the dent corn as ever before but for the flint there are three years when it has been larger. The extra water has made the yield of flint this year larger than any not irrigated yield except the first and third, while for the dent the yield is still larger than it has ever been. The total mean yield of water-free matter per acre has been, for the seven years:

On irrigated ground..	8,828
On not irrigated ground..	6,835
Difference..	1,993

But during the first four years when the soil had not been exhausted the mean gain due to irrigation was 3,543 lbs. of water-free matter per acre. During the last three years, however, the water added has not been able to materially increase the yield, the total mean being for the irrigated 7,363.5 lbs. and for the not irrigated 7,425.7 lbs. per acre, or 62.2 lbs. in favor of no irrigation.

THE YIELD OF POTATOES.

This season we have had a distribution of rain such as to cause the irrigation on a portion of the plots to produce a decrease of yield where rains following the second irrigation left the soil a little too wet.

On the north half of plot 6 which has a more sandy soil than the south half the yields were.

	Large tubers.	Total.
Irrigated	377.4	444.6 bu. per acre.
Not irrigated	322.1	363.2 bu. per acre.
Difference	55.3	81.4 bu. per acre.

On the south half where the soil is heavier and where it became too wet on the irrigated portion the yields stood:

	Large tubers.	Total.
Not irrigated	362.3	399.8 bu. per acre.
Irrigated	271.6	343.8 bu. per acre.
Difference	90.7	56.0 bu. per acre.

Here it will be seen that the irrigation cut down the yield of large tubers about 91 bushels per acre. This was due partly to rotting; but on the dryer ground the extra water made the yield 15 bushels per acre of large tubers more than the natural rainfall secured on the wetter soil.

The yields on plot 5 are in favor of no irrigation, this soil being on the whole heavier than that of plot 6. The yields stand:

	Not irrigated flat culture.	Not irrigated ridged culture.	Irrigated.
Large tubers per acre	364.2 bu.	325.1	336.7
Total per acre	422.1 bu.	375.8	386.4

In this case the flat culture is ahead of irrigation, and the irrigation is 11.6 bushels per acre ahead of the ridged culture. From these observations it appears clear that on the lighter and better drained soils irrigation is quite certain to increase the yield of potatoes fifty to one hundred bushels per acre.

We irrigated twice this year, but it is probable that the crop would have been larger if the last watering had been omitted.

UNAVOIDABLE LOSSES IN SILAGE.

F. H. KING.

An effort has been made the present season to experiment with small quantities of different materials which might be used in the production of silage, under conditions which would insure the entire exclusion of air, from the outside, but permitting the presence of so much of air as would be entangled in the silage material when filling the silo.

SILAGE EXPERIMENT 1.—PEAS, COW PEAS, OATS, RYE AND CORN IN PINT MASON JARS.

For this series there were used field peas with vines two feet high just coming into bloom, cow peas just coming into bloom, rye 16 inches high, oats just beginning to "shoot" and corn just coming into tassel.

The experiment was begun April 11, with material grown in the plant house, which was cut into 1.5 inch lengths and packed as closely as possible into pint Mason fruit jars; care being taken not to compress the material sufficiently to crush the tissue and express the juices. At first the cans were closed by simply screwing down the covers upon their rubber gaskets, supposing that they would remain sufficiently air tight to exclude the air, but later were sealed with sealing wax.

The cans were weighed daily on a balance accurate to one-tenth of a gram, and the losses during the first 15 days are given in the table below:

Table showing the daily loses in green weight of silage made in pint Mason fruit jars.

	Date.	Peas.	Cow peas.	Oats.	Rye.	Corn.
		Gms.	Gms.	Gms.	Gms.	Gms.
Weight in cans	....	352.2	377.8	370.7	317.9	366.1
Loss first 24 hours	Apr. 12	.15'	.3	.3	.1	.3
Loss second 24 hours	Apr. 13	.25	.2	.5	.2	.25
Loss third 24 hours	Apr. 14	Can exploded	.2	.45	.3	.15
Loss fourth 24 hours	Apr. 15	....	.2	.15	.1	.2
Loss fifth 24 hours	Apr. 16	....	.5	.5	.1	.3
Loss sixth 24 hours	Apr. 17	....	.3	.4	.4	.1
Loss seventh 24 hours	Apr. 18	....	.4	.4	.5	.8
Loss eighth 24 hours	Apr. 19	....	.0	.3	.1	.0
Loss ninth 24 hours	Apr. 20	....	.2	.35	.3	.2
Loss tenth 24 hours	Apr. 21	....	.1	.55	.3	.1
Loss eleventh 24 hours	Apr. 22	....	.0	.4	.2	.0
Loss twelfth 24 hours	Apr. 23	....	.1	.35	.3	.0
Loss thirteenth 24 hours	Apr. 24	....	.1	.25	.5	.1
Loss fourteenth 24 hours	Apr. 25	....	2	.3	.4	.15
Total loss	....	....	2.8	5.2	3.8	2.15
			Lbs.	Lbs.	Lbs.	Lbs.
Loss per 1,000 lbs	....	....	7.41	14.03	11.96	5.87
Loss per ton	....	....	14.82	28.06	23 92	11.74

It will be seen that the greatest loss in wet weight was from the oats, the rye standing second, while the corn sustained the smallest loss. The cow peas sustained a comparatively small loss also. It should be said that the rye exploded its can at the end of 15 days, as had been done by the peas at the end of 48 hours. When the oats were removed from the can they had developed a very strong and unpleasant odor, rendering them unfit for silage in such a condition.

The can containing the corn was not opened, and at the end of 136 days had sustained a gross loss of 1.62% of the weight when put in. A portion of this loss, however, was certainly water, for a similar jar containing only water sustained a loss of 1.3 gms. in the same time. If water was lost from the silage jar at the same rate, the loss of materials, other than water, would be only 1.27% of that put into the jar. We do not know what the loss in dry matter has been, but it is clear that could 100 tons of silage be carried under similar conditions the loss in weight would be between 1.62 and 1.27 tons.

EXPERIMENT 2.—ALFALFA, PEAS, COW PEAS, OATS AND CORN IN PINT MASON FRUIT JARS.

In these cases the trials with the peas, cow peas, oats and corn are a repetition of Experiment 1, except that the plants are all

27 days older. The alfalfa was taken from the field May 8 when 6 to 8 inches high. The materials in each case were cut short and closely packed so as to have a mean weight of 33.6 lbs. per cubic foot. In the following table the daily losses are given.

Table showing daily losses in silage in pint Mason jars during 108 days.

Date.	Alfalfa.	Peas.	Cow peas.	Oats.	Corn.	Date.	Alfalfa.	Peas.	Cow peas.	Oats.	Corn.
	Gms.	Gms.	Gms.	Gms.	Gms.		Gms.	Gms.	Gms.	Gms.	Gms.
May 9......	.60	.20	.15	.15	.10	May 31......	.00	.15	.10	.05	.25
10......	.40	.35	.15	.15	.30	June 1......	.10	.15	.05	.15	.10
11......	.50	.50	.10	.55	.35	2......	.05	.05	.00	.10	.05
12......	.35	.80	.05	.15	.50	3......	.05	.05	.00	.00	.05
13......	.25	.20	.00	.15	.30	4......	.00	.05	.00	.00	.05
14......	.40	.10	.20	.10	.70	5......	.05	.05	.00	.10	.05
15......	.20	.00	.20	.20	.55	6......	.05	.10	.00	.10	.00
16......	.20	.15	.10	.10	.65	7......	.05	.10	.00	.05	.15
17......	.00	.00	.00	.00	.40	8......	.05	.10	.00	.00	.00
18	.05	.00	.10	.05	.55	9......	.05	.00	.15	.10	.00
19......	.00	.00	.00	.00	.45	10......	.00	.05	.00	.00	.00
20......	.00	.00	.00	.00	.55	19......	.55	.45	.00	.35	.00
21......	.15	.00	.05	.05	.75	29......	.40	.20	.00	.15	.00
22......	.15	.20	.15	.40	.75	July 16......	.80	.15	.00	.30	.30
23......	.10	.05	.05	.05	.65	31......	.50	.25	.20	.25	.55
24......	.00	.05	.10	.15	.55	Aug. 25......	.20	.00	.00	.10	.50
25......	.10	.05	.10	.30	.55						
26......	.10	.10	.05	.05	.65	Total....	6.65	5.30	2.15	5.35	12.55
27......	.00	.20	.03	.25	.25	Green wt.					
28......	.05	.15	.00	.30	.50	put in can.	221.2	221.05	235.65	243.3	254.35
29......	.00	.03	.00	.10	.85	Per cent. of					
30......	.15	.20	.05	.20	.10	loss........	3.01	2.40	.91	2.30	4.93

It will be seen from this table that there has been a slow and somewhat uniform rate of loss in all cases, but decreasing after the maximum is passed. The percentage loss figured on the green weight ranges from less than one per cent., in 108 days of hot summer weather for the cow peas, to a maximum of only 4.93 per cent., in the case of the corn, the average loss being only 2.71 per cent. In the case of the corn where the losses are heaviest the can was not sealed quite as closely as the others, as was proven by the formation of a little mould on the top.

EXPERIMENT 3.—WITH MATURE CORN, CLOSELY AND LOOSELY PACKED IN PINT AND QUART MASON JARS.

The object of this trial was to see if the degree of closeness of packing would have any material effect on the losses, provided outside air is excluded. It is now well established that close packing of silage is a very important matter in all silos where the walls are at all open, but it is not yet demonstrated how im-

portant close packing at the time of filling may be in the best built silos. When filling is rapid, and little tramping is practiced, there is entangled with the silage a larger volume of air than where the filling is slower and careful tramping is followed.

To make these trials, well matured corn had its stalks, leaves and ears cut into short sections and one-half of each piece was put into a pint Mason jar and the other half put into a quart jar of the same pattern; the aim being to secure two closely similar samples, one of which should be packed as closely as possible and the other given just double the space for the same amount of material. Three pairs of jars were filled in this way, to one of which water was added after packing, so as to expel the entangled air. The covers in this series were simply screwed down as closely as possible on the rubber gaskets but no sealing wax was used as in the two previous trials.

The observed losses are given in the table which follows. In the case of the pair to which water was added the gases carried over so much water at first that some of it had to be removed to prevent capillarity drawing it out under the gaskets, which would prevent measuring the losses.

Table showing the losses from corn silage in Mason jars packed closely and loosely.

DATE.	FIRST PAIR.		SECOND PAIR.		THIRD PAIR WITH WATER ADDED.	
	Quart.	Pint.	Quart.	Pint.	Quart.	Pint.
Total	15.35	12.05	14.60	13.75	8.40	2.15
Green weight of material in can	296.9	285.25	351.15	330.15	315.8	311.2
Per cent. of loss	5.17	4.22	4.16	4.16	7.48	1.95

It should be noted that in this case the table shows a loss of only 2 to 7.5 per cent., of the green weight put into the silos during the interval of 93 days, the largest loss being in the quart can to which water was added. It cannot be said, however, that this large loss was due to the water because its mate, to which water was also added, lost less than any other.

The experiment is not conclusive, either, as to the influence of the larger amount of air left in at the start, entangled in the silage of the quart cans, causing a greater loss, for although there

is one pair where the quart can sustained the greater loss, in the other pair the loss was equal in the two cases. The experiment must be repeated under conditions which will certainly exclude all air and make evaporation impossible.

EXPERIMENTS 4 AND 9. — MEASUREMENT OF THE GASEOUS PRODUCTS GIVEN OFF FROM CORN SILAGE.

In these two experiments corn was cut and put into galvanized iron cylinders and connected with gas receptacles as represented in Fig. 24, so that the gases evolved could be collected and measured. The cans were closed air-tight by soldering in metal covers provided with outlets to which the rubber tubes shown in the cut could be connected.

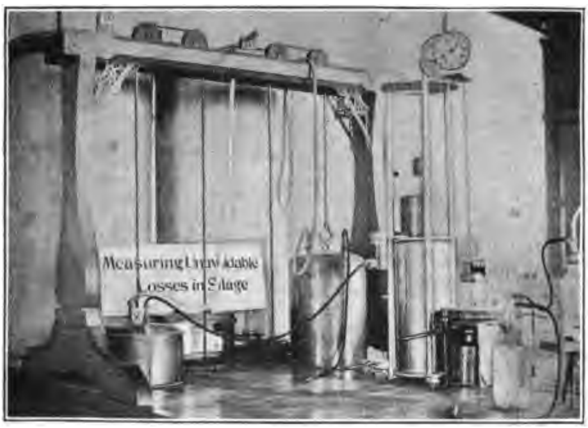

FIG. 24.—Showing method of measuring, rate of loss of gaseous products from silage.

Experiment 4 was started May 26 from corn grown in the plant house which was in the early milk stage when cut.

Experiment 9 was started Julv 11 from corn also grown in the plant house, this being thoroughly matured and the ears husked from it, only the stalks and leaves being cut into the silo. In silo No. 4 the green weight put in was 72.5 lbs., and the amount cut into silo No. 9 was 71.03 lbs.

On Sept. 8 silo No. 4 had lost during 105 days 2.4 lbs., or

3.31 per cent., while silo No. 9 had lost during 59 days 2.3 lbs., or 3.24 per cent.

The gases given off from these two silos were collected and measured twice daily, then daily, and finally at longer intervals, when the rate of generation had become slower. The amount of gas measured on each date from the two silos are given in the table which follows, reduced to a pressure of 29.922 inches and temperature of 60° F.

The total amount of gas collected from Silo 4 was 20.10 cubic feet and from Silo 9 it was 17.05 cubic feet; this, it will be seen, is three to four times the volume of the silage.

Table showing generation of gases by corn silage expressed in cubic centimeters at 60° F. and 29.92 inches of barometric pressure.

DATE.	SILO NO. 4.			SILO NO. 9.			
	Gas c. c.	Date.	Gas c. c.	Date.	Gas c. c.	Date.	Gas c. c.
May 28......	11,970	June 17...	5,799	July 12...	18,819	Aug. 6...	8,519
29......	11,760	18...	6,988	13...	29,040	7...	7,388
30......	29,700	19...	406*	14...	30,110	8...	8,504
31......	35,000	20...	7,745	15...	32,860	9...	8,352
June 1......	37,045	21...	4,643	16...	28,150	10...	5,667
2......	29,650	22...	2,566	17...	18,212	11...	4,908
3......	25,250	23...	4,746	18...	19,580	12...	3,233
4.....	22,850	24...	12,716	19...	19,753	14...	3,894
5......	20,801	25...	9,149	20...	15,574	15...	2,834
6......	21,267	26...	9,154	21...	14,889	16...	2,248
7......	18,621	27...	8,079	22...	17,158	18...	3,844
8......	14,568	28...	5,576	23...	14,819	19...	5,209
9......	13,810	29...	3,015	24...	7,496	20...	3,913
10	8,435	July 2...	19,700	25...	13,190	21...	3,532
11......	8,276	5...	21,010	26...	12,040	23...	3,735
12......	8,469	10...	26,290	27...	10,060	24...	4,199
13......	8,542	16...	19,0[illegible]0	28...	10,830	26...	3,446
14......	5,685	25...	17,970	29...	11,330	27...	1,881
15......	7,116	Aug. 4...	21,490	30...	6,720	28...	1,812
16......	6,866	15...	7,552	31...	9,122	29...	2,741
				Aug. 1...	8,381	30...	2,848
			569,325	2...	7,268	31...	2,416
				3...	5,078	Sept. 2...	1,141
				4...	7,784	4...	2,334
				5...	7,096	6...	7,615
							482,972

* stop cock left open by mistake.

The gas generated by the No. 9 silo is represented graphically in Fig. 25 where it will be seen that the rate of generation increased very rapidly from the start, reaching its maximum between the fourth and fifth day, when it again fell off rapidly. The volume of gas evolved on the day of maximum rate was very nearly one-fifth that of the silage itself, which was, however, very loosely packed.

During a large number of intervals a large sample of the gas was drawn into a receptacle containing caustic soda and the carbonic acid absorbed, at the same time measuring the total and residual gas treated.

There was apparently a considerable variation in the ratio of CO_2 to the other gases but the mean ratio found was 74.02 per cent. of CO_2 to 25.98 of residual gas in the case of silo No. 4 and 72.24 to 27.76 in No. 9.

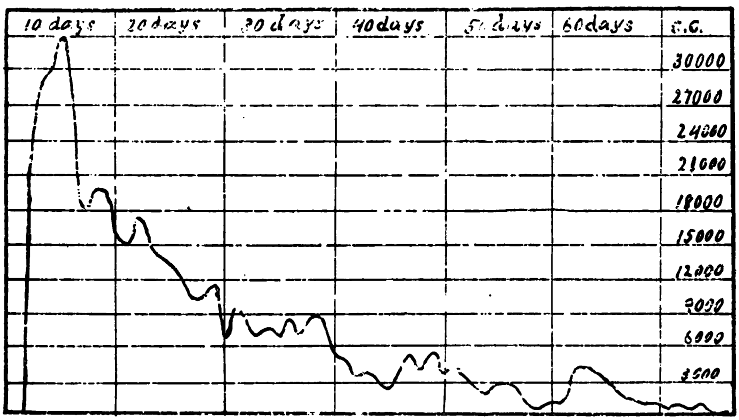

FIG. 25.—Showing the rate of loss of gaseous products from corn silage.

The gases coming from Silo 9 during the first five days were in the ratio of 43.01 of CO_2 to 56.99. This different ratio is probably largely due to the dilution with atmospheric nitrogen which was in the silo at the start.

EXPERIMENT 8. — MEASUREMENT OF GASEOUS PRODUCTS GIVEN OFF FROM CLOVER SILAGE.

On June 18, 176.1 lbs. of medium clover was cut and packed in a galvanized iron cylinder, packing so as to give 22.5 lbs. per cubic foot. This can was soldered air-tight and arranged so that the gases from it could be measured as in the preceding cases.

On July 16, after 28 days, the clover had lost in weight 1.45 lbs. or .8 per cent. of that put in. On August 25 it had lost 2.1 lbs. or 1.19 per cent. after 58 days.

The total volume of gas given off up to August 25 was 15.7 cubic feet, a volume double that occupied by the silage.

During the first five hours after sealing the silo there was given off 12,000 cc. of gas but during the 22 days preceding September 6, the amount was only 47,993 cc. or a mean of 91 cc. per hour instead of 2,400 cc., the rate at the start.

The ratio of carbon dioxide to other gases was, during the first five days, 47.10 to 52.90, but after this date it averaged 78.41 to 21.59.

INFLUENCE OF POTASH SALTS ON BLACK MARSH SOILS.

F. H. KING AND A. R. WHITSON.

The beneficial results which followed the application of potassium carbonate and wood ashes to the marsh soils of the Station in 1899, and which are reported in Bulletin 80 led to a more extended series of studies this season of the relative effect of the different forms of potash salts when used as fertilizers for these lands.

Four kinds of potash salts, furnished by the German Kali Works, were used at the Station and on three other farms in different portions of the state. The trials at the Station in the field were in three series as follows:

Series I. To compare the relative effectiveness of potassium sulfate, potassium chloride, potassium magnesium carbonate and Kainite.

Series II. To compare the relative efficiency of potassium sulfate when applied in different ways and in different amounts.

Series III. To compare the relative efficiency of different amounts of potassium chloride when applied in different amounts and in different ways.

SERIES I.—RELATIVE EFFECTIVENESS OF POTASSIUM SULFATE, POTASSIUM CHLORIDE, POTASSIUM MAGNESIUM CARBONATE AND KAINITE ON BLACK MARSH SOIL.

In this series the salts were all applied in the hill in such amounts as to give equal quantities of potassium. The application was made on June 21, after the corn was up, by brushing the dry earth away in a circle one foot in diameter around each

hill, sprinkling the fertilizer on the moist soil and then covering it by returning the earth brushed away.

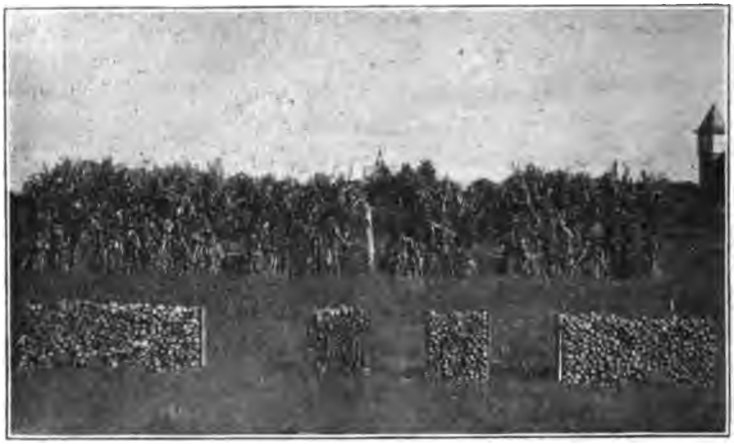

FIG. 26.—Showing influence of potash salts on the yield of ear corn and of stalks grown on black marsh soil. The two middle piles of ears in the foreground came from the two center bundles of stalks in the background, and grew on the untreated soil. The outer piles of corn and bundles of stalks were grown under the influence of potash salts.

The salts were applied to single rows in regular rotation, each treated row being separated by three others not treated; and at the rate of 263.3 lbs. of the sulfate, 171 lbs. of the chloride, 649.8 lbs. of the carbonate and 644.6 lbs. of kainite per acre. The work was duplicated on each of two plots and when the corn was ripe, but leaves and stalks yet green, 20 hills in each row were husked and the stalks and ears weighed, giving the results which appear in the next table.

Table showing the effect of applying, in the hills of corn on black marsh soil, equal amounts of potassium in the form of sulfate, chloride, potassium magnesium carbonate and kainite. Yields of green weight per acre in tons and bushels of 100 pounds.

	K_2SO_4	Blank.	K Cl.	Blank.	Kainite.	Blank.	(K Mg) CO_3	Blank.
Plot A, tons.	16.66	9.16	20.43	9.42	19.27	10.28	19.04	8.81
Ears, bushels...	94.1	29.4	128 2	36.6	108.9	44.4	115.7	33.8
Plot B, tons............	15.35	6.91	17.19	8.26	16.39	8.28	17.10	7.11
Ears, bushels...	83.8	26 4	107.2	36.0	87.6	38.9	104.9	27 9
Av. No. tons	16.00	8.04	18 81	8.84	17.83	9.28	18.07	7.96
Average bushels.........	88.8	28 0	117.6	36.4	98.2	41.7	110.3	30.8

It is clear from these figures that the potash salts have increased the yield very much, there being on the average of the

whole, three times as much ear corn and twice as much total ears and stalks combined.

The comparative efficiency of the different salts can only be ascertained by comparing the yields of each treated row with the untreated ones on either side. This mode of comparison should always be followed in plot studies and it is especially important here because of the inequality of the soil. Making the comparisons in this way the relative efficiencies stand as below:

Potassium sulfate increased the stalks 2.042 times, and ears 4.434 times.
Potassium chloride increased the stalks 1.893 times, and ears 3.661.
Potassium Mg. carbonate increased the stalks 1.842 times, and ears 3.045 times.
Kainite increased the stalks 1.814 times, and ears 2.519 times.

The cost of these fertilizers per acre would be, counting the potash five cents per pound, $4.40, or $4.75 counting sacking and freight from Chicago or Milwaukee to Madison.

The corn grown after the potash salts is worth more than that grown on the untreated soil, pound for pound, because it contains on the average 1.65 times the amount of ears per ton.

If the corn is counted of equal value and worth $2.00 per ton the value of the increased product would be $17.68 per acre, or a net gain per acre of $12.93.

SERIES II.—INFLUENCE OF DIFFERENT AMOUNTS OF THE SAME POTASH SALT ON THE YIELD OF CORN FROM BLACK MARSH SOIL.

In this series only two salts were used, the sulfate and the chloride. The sulfate was applied at the rate of 640 lbs. per acre, and one-half this amount. The chloride was applied at the rate of 171 lbs. per acre, and one-half of this quantity; the salts being applied to a series of rows in rotation, leaving three untreated rows between each pair. The mean effectiveness of each of the two salts is expressed below:

640 lbs. potassium sulfate per acre increased the yield of stalks 1.70 and ears 2.29 times.
320 lbs. potassium sulfate per acre increased the yield of stalks 1.51 and ears 1.91 times.
171 lbs. potassium chloride per acre increased the yield of stalks 1.41 and ears 1.48 times
85.5 lbs. potassium chloride per acre increased the yield of stalks 1.33 and ears 1.48 times.

It should be stated that the smaller effectiveness shown in this and the next table is due to the fact that these rows crossed areas

which had been given farmyard manure in 1898 or 1896, the influence of which was still very apparent.

It is clear from the results that the smaller amounts of salts used were not large enough to permit these soils to produce their maximum yields, but the increase due to the heavier treatment is much less than proportional to the quantities applied.

SERIES III.—INFLUENCE OF DIFFERENT MODES OF APPLYING SALTS TO MARSH SOILS ON THE YIELD OF CORN.

In these trials only two salts were used, the sulfate and chloride and they were applied in two ways, broadcast and in the hill. The amounts used per acre are those given in the table of the last section.

Potassium sulfate in the hill increased the yield of stalks 1.72 and of ears 2.37 times.
Potassium sulfate broadcast increased the yield in stalks 1.81 and of ears 1.91 times.
Potassium chloride in the hill increased the yield of stalks 1.44 and of ears 1.82 times.
Potassium chloride broadcast increased the yield of stalks 1.42 and of ears 1.24 times.

It will be seen that so far as the yield of stalks is concerned there is but little difference between the hill and broadcast application, but with the ear corn the application in the hill has materially increased the yield with both salts.

COMPARATIVE EFFICIENCY OF POTASH SALTS WHEN PLACED AT DIFFERENT DEPTHS IN THE SOIL.

The present season the 36 3-foot cylinders of marsh soil in the plant house were divided into three groups of 12 each, to be treated with three kinds of potash salts, placed at four different depths in the soil. The object of this series was to ascertain whether the potash salts are beneficial to the crop in any other way than that of supplying plant food. In view of the fact that an "official" analysis of these soils shows them to contain as much potash as good clay soils do, it appeared possible that the large beneficial effects associated with the use of these salts might be due to some indirect influence, perhaps in neutralizing some principle in the soil prejudicial to plant growth which was developed near the surface or concentrated there by evaporation and capillarity. It was assumed that if the potash was used simply as a plant food it would become readily available if applied anywhere between the surface and 9 inches below; but that

if it acted in some other way it would be less effective at considerable distances below the surface.

For the experiments each cylinder was divided at the surface into four compartments. The soil in each cylinder was removed to a depth of 6 inches. Upon the new surface were placed on edge two 8-inch boards at right angles; then the soil in one quarter was removed three inches lower, that in another was left unchanged and a third had its surface raised three inches while the fourth was brought back to the original level.

On these four surfaces the potash salts were distributed, dissolved in one quart of water, after which the soil removed was replaced, bringing the four quadrants back to their original level. With this arrangement the salts were applied:

1. At the surface.
2. Three inches below the surface.
3. Six inches below the surface.
4. Nine inches below the surface.

The salts used were the common potassium nitrate and sulfate of druggists, and the muriate form of potassium chloride obtained of the German Kali Works. The amounts used in each case were 10.8 gms. of $K_2\ SO_4$, 12.1 gms. of KCl, or 12.75 gms. of $K\ NO_3$ to each quarter of the cylinder, or at the rates of 77.2, 86.5, 91.1 lbs. per acre respectively if applied in hills 3 feet 8 inches each way, or 588.4, 659.3, 694.3 respectively if covering the whole surface of the field.

The corn was planted four kernels in a hill and then thinned to two stalks after the plants were well started.

Table showing the differences in yield associated with the application of three kinds of potash salts at four different depths in the soil.

	NO SALTS ADDED.	SALTS ON SURFACE.	SALTS 3 IN. BELOW SURFACE.	SALTS 6-IN BELOW SURFACE.	SALTS 9-IN BELOW SURFACE.
	Lbs. dry matter per acre.	Lbs. dry matter per acre	Lbs. dry matter per acre.	Lbs. dry matter per acre.	Lbs. dry matter per acre.
Potassium nitrate, poorest soil	....	9,896	18,660	11,430	10,260
Potassium nitrate, better soil	....	7,369	10,080	10,830	10,070
Potassium sulfate, poorest soil	4,974	11,640	8,521	11,292	8,603
Potassium sulfate, better soil	5,521	7,608	11,500	10,937	10,725
Potassium chloride, poorest soil.	5,739	10,260	14,620	11,615	10,505
Potassium chloride, better soil	6,021	8,559	9,516	11,405	11,775
General average.........	5,564	9,222	11,816	11,251	10,326

From this table it appears that

1. The untreated soils have given yields only about one-half those from the treated soils.

2. While the yields on the untreated poorest soils are less in every case than those from the better soil, the same amount of potash given to the poorer soil as that given to the better has in nearly every case produced a larger mean yield than the better soil did.

3. The salts when applied at the surface have produced the least general increase in yield, the nine-inch depth standing next while the 3-inch depth has given the largest general average.

4. The data appear to indicate that the corn cannot utilize the potash as well for food when applied at the surface or nine inches below as at intermediate depths, or else that the salts exert an influence between two inches and six inches which is helpful in other ways than as plant food.

The fact that the potash salts have increased relatively the yield of grain so much more than they have the stalk, suggests, in conjunction with the investigations of Nobbe, Schroeder, Eardmann and Hellriegel regarding the relations of potash in the soil to the formation of starch and sugar, that although chemical analysis shows an abundance of potash in the soil it, for some reason, is in a very unavailable form; and, if true, this is another of many cases where a mere chemical analysis of a soil, as now conducted, fails to give the needed information.

An analysis of corn grown on these soils, treated and not treated with potash, showed for the former 1.03 per cent., and for the latter .83 per cent. of potash in the dry matter.

An effort was made to test the hypothesis of an injurious principle existing in these soils by selecting a quantity of the surface soil from places where corn was making almost no growth and washing this by placing it in a grain sack in a can of water and working thoroughly to dissolve out whatever was possible. These washings made fresh twice a week were applied to hills of corn which were making good growth, to see if it would be possible to retard it. No definite effects were shown.

EXPERIMENTS AT OTHER PLACES.

The potash salts applied to marsh soils in other parts of the state made improvements in the crop plainly observable to the eye wherever the salts were worked into the soil.

Where we applied them broadcast and the soil was not subsequently cultivated, so as to work the salt into the ground, the observable effect was much less noticeable. Sown on "run-out" marsh meadow at Whitewater it produced no observable effect. The wood ashes applied to clover and timothy on these lands at Marathon City, before the frost was out in the spring, increased the growth of the hay so much that wherever the ashes were spread the grass was much stronger even in the second crop.

The kainite, sulfate and muriate applied to millet increased the growth very materially and so did the same salts when applied to tobacco, and cabbage at Windsor.

SOLUBLE SALTS OF CULTIVATED SOILS.

F. H. KING AND A. R. WHITSON.

Work reported under this head in the 16th Annual Report, p. 219, has been continued the present year under better conditions and has been pushed more systematically and extensively.

The chief effort has been devoted to a study of the amount of nitric nitrogen in field soils under crop conditions throughout the season; at the same time following a parallel control series of studies in our plant house cylinders as a check upon the field work.

Work in the field was begun as soon as the frost was out of the ground and the nitric nitrogen content of the nine field plots, covering ten acres, has been determined at the middle and beginning of each month from April 18 to September 18, or eleven times.

In eight of these cases samples were taken in one foot sections to a depth of four feet, at the other intervals to a depth of two feet. By doing this we have secured a detailed record of the changes in the amount and distribution of nitric acid through an entire growing season for three plots of corn, two plots of potatoes, two plots of clover, one plot of alfalfa and one plot of oats.

Besides this we have made other studies in our plant house cylinders where the amount of soil and moisture are not only known but under complete control.

Side by side with the nitric acid determinations we have made a study of the total soluble salts as indicated by the electrical resistance, the two sets of determinations being usually made on each set of samples.

The amounts of water present in the field soil have been re-

corded at each interval and for each depth and the total amount of dry matter produced on each plot has also been recorded; so that we are now in possession of a fairly accurate set of data showing the amount of nitric acid and the amount of water present in the soil, throughout the season, upon which known amounts of nine crops have been grown.

The samples of soil have been taken by our Field Assistant, Harvey Sandel; the nitric acid was determined by the junior and the soluble salts by the senior authors of the paper. Our data are derived from more than 3,000 cores of soil, each one foot long.

INFLUENCE OF TILLAGE ON THE DEVELOPMENT OF NITRIC ACID AND SOLUBLE SALTS.

Series I.

The field work done last year under this head was repeated during the winter in our plant house cylinders, which are 52 inches deep and either three feet or eighteen inches in diameter.

On December 2d to 9th, after the crops had all been removed, four inches of soil were taken from each cylinder and placed in one vessel and then a second layer removed to place on top. The soil was then spaded to a depth of eight inches, water enough added to bring them to standard weight and after this had been absorbed the soil removed was returned. After this treatment the cylinders stood five days, for the surface to become moistened by capillarity, when all were leveled and tamped with a flat metal disk one foot in diameter and weighing 27.5 lbs.

The cylinders were then divided into three groups as follows:

1. Those not cultivated.
2. Those cultivated once per week.
3. Those cultivated once in two weeks.

The stirring of the soil was done to a depth of three inches with a flat tined potato fork provided with a gauge to fix the depth to which the soil was stirred. The cylinders were all weighed on December 14, and the experiment started, continuing until March 15, or 91 days, no water being added to either group of cylinders in that time.

The soluble salts contained in the first, second and third feet of these cylinders was determined before the soil was disturbed and samples were quickly dried at a low temperature for the determination of the nitric nitrogen after the junior author should take up his work at the Station.

In the table which follows are given the changes in soluble salts as found by the electrical method, and in nitric nitrogen as found by the phenol-sulphonic acid method.

Table showing the gains and losses of nitric nitrogen and soluble salts from clay loam after 93 days with different methods of tillage and without crops.

	NOT CULTIVATED.			CULTIVATED ONCE PER WEEK.			CULTIVATED ONCE IN TWO WEEKS.		
	Nitric nitrogen in parts per million of dry soil.								
	1 ft.	2 ft.	3 ft.	1 ft.	2 ft.	3 ft.	1 ft.	2 ft.	3 ft.
After corn.......	26.45	11.84	12.26	16.84	5.46	8.70	18.90	7.97	8.75
After clover.....	26.18	13.40	11.99	25.96	10.03	11.92	22.07	10.90	10.95
After oats.......	29.06	10.42	11.51	9.59	6.97	11.52	....	....	....
After potatoes..	—22.25	11.30	8.69	—29.36	6.07	12.07	....	....	....
After beans, timothy and beets	34.53	3.75	7.91	13.08	—6.22	—2.04	....	....	....
Average.....	18.79	10.14	10.47	7.21	4.46	8.43	20.49	9.44	9.85
	Total soluble salt in parts per million of dry soil.								
After corn.......	107.8	34.1	51.9	59.4	18.8	21.8	65.3	17.8	— 5.0
After clover.....	126.9	49.2	25.7	121.7	107.4	29.0	105.3	37.1	23.0
After oats.......	85.8	53.4	24.1	44.3	25.9	22.5	....	....	....
After potatoes..	—120.1	15.3	2.2	—150.9	—1.7	35.6	....	....	....
After beans, timothy and beets	112.0	—110.8	10.5	38.3	—135.2	—30.5	....	....	....
Average.....	62.5	8.24	22.83	22.56	3.04	15.68	85.3	27.45	9.00

No water has been given to any of these cylinders during the 93 days and there was no leaching so that whatever gain or loss of nitric nitrogen occurred must be explained by its production in the soil or its conversion into some form not responding to the method; unless, indeed, they be explained by error of method or of observation.

The general conclusions suggested by this study may be stated as follows:

1st. Nitrification has taken place at all depths down to three feet below the surface, and hence that in these cases it is not a process limited to the surface few inches.

2nd. As a general rule there has been the highest increase of

nitric nitrogen in the surface foot and the increase in the third foot has generally exceeded that in the second foot.

3rd. The increase of nitric nitrogen has been greater at all depths, as a rule, where the soils have not been cultivated than where they have.

4th. In two groups of cylinders there has been a tendency for the nitric nitrogen to decrease rather than increase.

5th. There has been 22 per cent. more nitric nitrogen developed from the soil after clover than from the soil after corn, and 13 per cent. more than from that after oats during the 93 days.

6th. But the soil after growing corn the same number of years that the other had grown clover began the experiment with nearly three times as much nitric nitrogen in it as the soil after clover did and it closed the cultivation period with 17 per cent. more nitric nitrogen.

7th. The soil, after oats, began the experiment with 2.6 times as much nitric nitrogen as the clover soil did and it closed the cultivation period with 13.8 per cent. more nitric nitrogen.

8th. The fertilizing power of clover appears to depend more upon the amount of nitrogenous material left in the soil which is capable of rapid nitrification than upon nitric nitrogen accumulated by it.

9th. With the marsh soil yielding poor crops there was in both cases a heavy gain of nitric nitrogen in the first foot but in the soil giving better yields there was only a small gain in the not cultivated ground and a loss in the surface foot of cultivated ground. Indeed there was a total mean gain in the poorer soil of 37.47 parts per million but one of only 2.97 parts per million in the better soil for all three feet, while in the case of the clay loam the total mean gain was 8.77 parts per million of nitric nitrogen.

We have in the plant house 9 cylinders with plastering sand upon which clover and alfalfa were grown last year and the total product returned to the sand, with a view of developing humus in it. There are four other cylinders containing the Minong pine barrens soil upon which alfalfa was grown, the total crop being returned to the soil after each cutting.

These cylinders were carried through the season of 93 days, with those reported above, as fallow ground, and the nitric nitrogen determined at the close, with the results given in the table which follows:

Table showing the changes in nitric nitrogen which had occurred after an interval of 93 days. Results are in parts per million of dry sand.

	After clover on plastering sand.			After alfalfa on plastering sand.			After alfalfa on pine barrens sand		
	1st ft.	2d ft.	3d ft.	1st ft.	2d ft.	3d ft.	1st ft.	2d ft.	3d ft.
Total nitric nitrogen at close....	14.5	5.95	3.40	23.92	12.60	12.63	52.03	23.22	12.68
Total nitric nitrogen at start. ..	0.00	0.00	0.00	1.40	1.28	0.83	1.66	0.50	0.62
Gain	14.50	5.95	3.40	22.52	11.32	11.80	50.37	22.72	12.06

It will be seen that in this case there has been a notable change in the nitric nitrogen, amounting to 17.18 parts per million of dry sand as a mean of the whole series for the three feet in depth; while the mean gain in the clay loam after clover, was only 15.93 parts per million of dry soil.

These results corroborate the statement made under 8th, and suggest that the clovers leave a soil in such a condition that the rate of development of nitric nitrogen in them is more rapid than after other crops, like oats and corn.

Nitric Nitrogen and Soluble Salt in the Stirred Soil of Cultivated Ground and Near the Surface of that not Stirred.

The data presented in the last section do not indicate that surface tillage to a depth of three inches exerts a notable influence on the formation of nitrates or other salts below the soil stirred. What evidence they bear appears to suggest that under those conditions the tillage may have retarded the process under consideration.

At the close of that experiment a composite sample of soil, from all of the loam cylinders not cultivated, was taken of the surface half inch and of the second and third half inches to note the degree of concentration of salts formed. Similar samples were taken from the marsh soils. Composites, too, were taken of all of the mulches developed in the cultivation of the several

groups of cylinders. The determinations of the salts in these samples are given in the table below:

Table showing the nitric nitrogen and soluble salts in the surface of soils not cultivated and in the stirred portion of cultivated soils in parts per million of dry soil.

		Surface half inch.	2d and 3rd half inch.	Difference.
Soil not cultivated:				
Clay loam	Soluble salts.	1,198	170.4	1,027.6
	Nitric nitrogen	330.6	26.91	303.69
Marsh soil yielding poorest crops	Soluble salts	4,685	2,300	2,385
	Nitric nitrogen	829.44	324.0	505.44
Marsh soil yielding better crops	Soluble salts	2,678	1,250	1,428
	Nitric nitrogen	297.16	75.39	221.77
		Cultivated once per week.	**Cultivated once in two weeks.**	**Difference.**
Stirred portion of soil:				
Clay loam	Soluble salts	321.6	244.2	77.4
	Nitric nitrogen	98.16	53.01	45.15
Marsh soil yielding poorest crops	Soluble salts	2,174	1,566	608
	Nitric nitrogen	353.16	168.72	184.44
Marsh soil yielding better crops	Soluble salts	1,418	782	636
	Nitric nitrogen	99.14	65.02	34.12

In this table it will be seen that the soils stirred once per week have developed much more nitric acid than those stirred but once in two weeks, the clay loam showing an increase of 85.17 per cent., and since the soil was stirred three inches deep it represents one-fourth of an acre-foot, or 1,000,000 lbs., in round numbers, in which there was a gain of 45.15 parts per million of nitric nitrogen and when this is expressed as calcium and magnesium nitrates would weigh 248 lbs. per acre. This is nearly enough for 30 bushels of wheat.

In the case of the marsh soil yielding the poorest crops there was an increase of nitric nitrogen of 109.3 per cent. but on the other soil of the same type, giving the better yields, the increase was only 52.48 per cent.

These observations stand in such sharp and strong contrast, as to the influence of frequency of cultivation on the development of nitrates in a soil, that it appears strange that stronger evidence was not found when the samples of the first, second and third feet are compared; and that there was clearly stronger nitrification in the cylinders of clay loam not cultivated. To this it should be said that the stronger drying of the soil in cyl-

inders not cultivated resulted in more or less shrinkage away from the walls and that this would permit better aeration, because where the mulches were maintained there was less shrinkage and if shrinkage did occur, the stirring of the mulch would keep shrinkage cracks closed so far as a mulch could do so.

The stronger nitrification in the bottom foot of so many cylinders may be due to one or both of two causes: 1st. The cylinders have the construction and are filled as represented in Fig. 27. No water stands in the bottom of the cylinders and the caps on the outlets are only screwed on with the fingers and are not likely to be perfectly air-tight. It is not impossible therefore that some aeration may occur here but it is not clear how it can be large. 2nd. In those cases where we have washed out the roots of plants grown in such cylinders we have found that they form a dense mat on the bottom of the can and if this has occurred in these cases there would be more organic matter to decompose and give rise to nitric nitrogen.

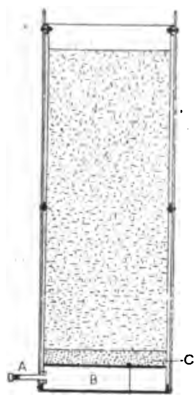

FIG. 27.—Showing construction of plant-house cylinders.

INFLUENCE OF FREQUENCY AND DEPTH OF TILLAGE ON THE FORMATION OF NITRIC NITROGEN AND SOLUBLE SALTS.

Series II.

We have conducted a second series of observations bearing upon the influence of tillage on the formation of nitrates, using the cylinders represented in Fig. 21, (Ann. Report, 1898, p. 135). Twenty of these were filled with a thoroughly mixed and uniform clay loam a little coarser than that used in the plant house. When filled they were divided into two groups of ten each, one set to be cultivated once per week and the other once in two weeks. In each set there were

1st. 2 cylinders not cultivated.
2d. 2 cylinders cultivated 1 inch deep.
3d. 2 cylinders cultivated 2 inches deep.
4th. 2 cylinders cultivated 3 inches deep.
5th. 2 cylinders cultivated 4 inches deep.

In developing the mulch it was done by removing the soil from the full cylinder to a depth of the desired thickness of mulch and then returning so much of it as needed to fill the cylinder level full without jarring or tamping.

The cultivation was done by removing the entire mulch into a dish and then returning it to place again each time.

The experiment was begun in December, 1899, and closed August 27, 1900. On this date the soil was removed from each cylinder in layers having the thickness designated in the table below.

Table showing the influence of depth and frequency of tillage on the development of nitric nitrogen in clay loams.

	Depth of sample.	Not cultivated.	CULTIVATED TO THE DEPTH OF 1 in.	2 in.	3 in.	4 in.
		Parts per million of dry soil.				
Cultivated once per week....	Surface to 1 inch	544.92	170.45	266.20	278.73	267.68
Cultivated once in two weeks		......	240.50	195.20	257.58	223.25
Difference..............	....	....	+70.05	71.00	21.15	44.43
Cultivated once per week....	1 inch to 2 inch.	173.52	134.48	256.52	278.98	295.74
Cultivated once in two weeks		......	105.41	65.39	281.43	129.60
Difference..............	....	....	29.07	191.13	+2.45	166.14
Cultivated once per week....	2 inch to 3 inch.	54.10	53.79	114.61	113.69	127.51
Cultivated once in two weeks		......	59.54	84.32	119.04	97.92
Difference..............	....	....	+5.75	30.29	+5.36	29.59
Cultivated once per week....	3 inch to 4 inch.	30.62	43.30	72.82	59.76	73.85
Cultivated once in two weeks		......	28.36	38.84	52.36	56.20
Difference..............	....	....	14.94	33 98	7.40	17.15
Cultivated once per week....	4 inch to 8 inch.	26.78	34.14	53.89	51.31	55.11
Cultivated once in two weeks		......	28.06	31.43	39.31	32.83
Difference..............	....	....	6.08	22.46	12.00	22.28
Cultivated once per week ..	8 inch to 12 inch	16.54	28 56	36.14	35.91	33.28
Cultivated once in two weeks		......	23.46	21.89	25.14	24.62
Difference..............	....	....	5.10	14.25	10.77	8.66
Cultivated once per week....	12 inch to 16 inch	4.84	....	....	....	....
Cultivated once in two weeks		......	8.04	7.33	6.68	6.60
Difference..............	....	....	....	....	....	....
Cultivated once per week....	16 inch to 20 inch	0.00	....	....	....	....
Cultivated once in two weeks		......	00	00	00	00
Difference..............	....	....	....	....	....	....

It will be seen from this table that there are but four cases where the nitrates developed under the cultivation once in two weeks are not less than those where the cultivation was once per week and this is true to a depth of a full foot at least.

It is unfortunate that only one of the series of cylinders was examined in the two lower layers, for the figures indicate that there would have been a difference even in the next layer.

It is to be noted that the lower layer which is completely saturated with water shows no nitric nitrogen and yet the cylinders have been kept supplied with water containing an average of about 5.4 parts per million of nitric nitrogen.

Since there was no nitric acid in the lower zone of soil it would appear that the nitric nitrogen found in the zones above must have either existed in the soil when the cylinders were filled or else it must have been developed during the interval of the experiment either from humus in the soil or in part from the humus and in part from a reduction product of the nitrates in the water added.

The amounts of nitric nitrogen in the surface foot of the plant house cylinders after 93 days of fallowing were, on the average for the clay loam

Not cultivated	162.42 lbs.
Cultivated once per week	116.20 lbs.
Cultivated once in two weeks	95.04 lbs.

The amounts of nitric nitrogen in the surface foot in the series of smaller cylinders at the close of 258 days were

	Pounds per acre foot.
Not cultivated	325.48
Cultivated once per week, 1 inch deep	217.60
Cultivated once per week, 2 inches deep	323.44
Cultivated once per week, 3 inches deep	441.24
Cultivated once per week, 4 inches deep	387.96
Cultivated once in two weeks, 1 inch deep	213.29
Cultivated once in two weeks, 2 inches deep	199 00
Cultivated once in two weeks, 3 inches deep	401.68
Cultivated once in two weeks, 4 inches deep	245.26

It will be seen that here is a very large increase of nitric nitrogen in a form immediately available in crop production. The amount produced under the three and four inch cultivation was in round numbers, 400 lbs. per acre of soil one foot deep. This is available nitrogen enough per acre to produce 250 bushels of wheat.

THE DEVELOPMENT OF NITRIC ACID IN FALLOW GROUND AND ITS LOSS THROUGH THE WINTER AND EARLY SPRING.

In the 16th Annual Report, page 237, it was shown that the mean amount of nitric nitrogen found in the upper four feet of the nine fallow plots had come to be 95.5 lbs. per acre on August 22. Before winter set in trenches were made on all sides of the fallow ground, throwing up the earth to form a border preventing any water which fell upon the ground running away, and to prevent any surface wash upon it, the object being to secure all leaching possible to natural precipitation and to prevent any other.

On April 30, 1900, samples of soil were taken in one foot sections in each of the nine plots to a depth of four feet and the nitric nitrogen determined, with results given in the table below.

Table showing the amount of nitric nitrogen found in fallow ground after the leaching of winter and early spring. Pounds per million of dry soil.

No. of plot.		1.	2.	3.	4.	5.	6.	7.	8.	9.
Apr. 30, 1900.......	1st foot.	75.90	58.31	58.08	55.22	51.66	51.25	38.02	44.34	48.26
Aug. 22, 1899.......		16.81	13.58	26.67	26.80	19.09	16.82	5.50	24 07	19.60
Apr. 30, 1900.......	2d foot.	15.81	16.75	7.97	6.51	13.06	15.66	17.33	18.56	14.85
Aug. 22, 1899.......		4.34	7.75	1.81	9.07	5.74	2.76	1.43	6.06	6.61
Apr. 30, 1900.......	3d foot.	2.46	4.75	4.93	4.89	3.94	7.35	6.04	8.24	6.71
Aug. 22, 1899.......		.70	.54	2.48	.80	0.54	1.37	0.95	0.54	3 01
Apr. 30, 1900.......	4th foot.	2.95	2.37	3.05	2.35	2.01	2.36	3.65	5.60	5.08
Aug. 22, 1899.......		.80	......	1.04	......	1.55	0.52	0.26	0.53	3.51

From this table it will be seen that there was more nitric nitrogen in the soil at the beginning of May, 1900, than was found after being cultivated every week or two weeks from May, 1899, until August 22, of that year, with no crop on the ground.

Since we do not know how much nitric nitrogen was formed between August 22 and the time of freezing in the winter we do not know how much leaching, if any, may have occurred. We do know, however, that the amount of leaching was so small as to leave the nitrates in the soil very large.

AMOUNT OF NITRIC NITROGEN IN FALLOW GROUND IN THE SPRING COMPARED WITH THAT NOT FALLOW.

If an average of the amounts of nitric nitrogen found in the surface four feet of the nine field plots in the spring is compared with the amounts found in the upper four feet of the nine fallow plots they will stand as given in the table below, and as shown graphically in Fig. 28.

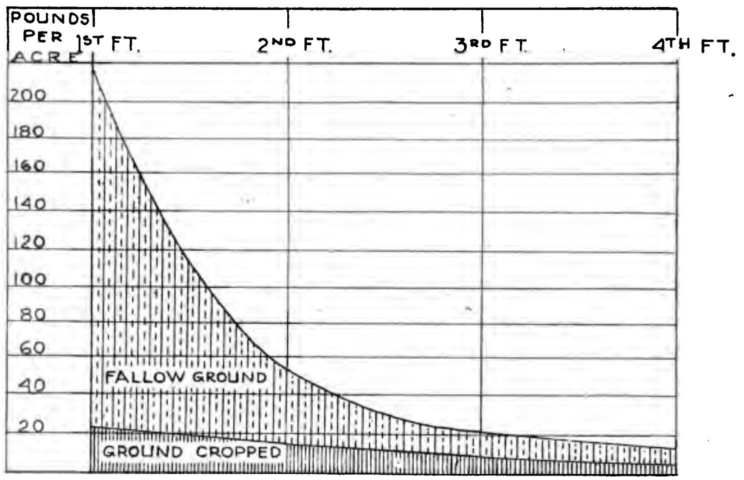

FIG. 28.—Showing the difference between the amounts of nitric nitrogen in fallow ground in the spring and in that not fallow.

Table showing the differences in the amounts of nitric nitrogen after the winter and early spring rains in ground kept fallow and free from weeds the previous season and that bearing crops.

Depth.	1st foot.	2d foot.	3rd foot.	4th foot.
Fallow plots, pounds per acre of dry soil.	212.00	56.22	21.91	13.11
Plots not fallow, pounds per acre dry soil	25.24	15 08	10.00	7.24
Difference............................	186.76	41.14	11.91	5.87

CHANGES OF NITRIC NITROGEN AND SOLUBLE SALTS UNDER FIELD CROPS DURING THE GROWING SEASON.

The work of studying the seasonal changes of nitrates and other soluble salts which was begun in 1899 has been continued this year, the work beginning in April, just after the frost left the ground, and continuing until September 19, when most of

the crops had completed their growth and some had been harvested.

The observed amounts of nitric nitrogen expressed as equal molecular weights of calcium and magnesium nitrates are represented graphically for the eleven dates in Figs. 30, 31, 32, 33, and with these data are given the total salts as indicated by the electrical method.

Referring to the nine plots under observation it will be seen that there are three of corn and two of potatoes and four of clover and alfalfa, but one of these carrying oats up to July 5th when they were cut for hay. Each of the clover plots has been cut twice, the alfalfa three times and the oat plot twice during the interval of observation and as these plots were irrigated when the rain was deficient they have produced as heavy yields as water and the fertility of the land would permit under the seasonal conditions which existed.

We have in this series of studies therefore two types of conditions, 1st, one where the crop covers the entire surface and intertillage cannot be practiced, and 2nd, the other where the crop occupies a portion only of the surface, where intertillage is practiced, and where a portion of the soil approaches the conditions which would be given by cultivated fallow ground, during the earlier part of the season.

To convey an idea of the differences in the nitrates and total soluble salts which developed under these two types of cultivation we have combined the data so as to show the mean amounts of nitrates and of total salts in each of the four feet on the eleven dates under the two types of conditions.

These combined data are shown graphically in the plate, Fig. 29, where it will be seen that the nitrates of the surface foot of the cultivated ground increased rapidly until the first of July, then falling very rapidly until August 1, when the crops are making the most rapid growth. From this point there is a slow rise until the corn is cut September 1, and the one more rapid until September 19, when the last observations are taken.
September 19, when the last observations are taken.

With the clovers, on the other hand, or crops not cultivated, the nitrates of the first foot have increased much more slowly,

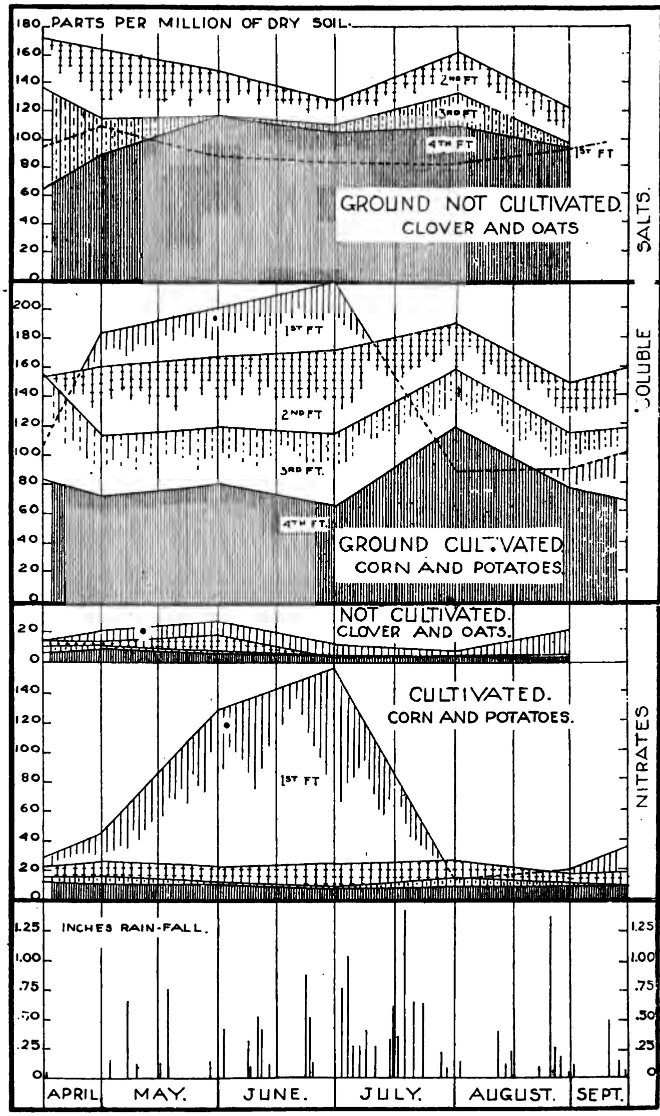

FIG. 29.—Showing the changes in the amounts of calcium and magnesium nitrates and of total soluble salts during the growing season in soils under cultivated crops, corn and potatoes, and under crops not cultivated, clover, alfalfa and oats.

reaching a maximum less than one-fifth as great June 1st or a month earlier. From this point they declined slowly reaching their lowest limit with the other plots on August 1, when they again rose until the end of the season.

The curves show that the nitrates in the surface foot under the corn and potatoes rose rapidly above those in any other depth until the 1st of July when they were about five times as concentrated as in the 2nd and twenty-one times as in the fourth foot; but in thirty days more, at the beginning of August when these crops were growing rapidly, the nitrates had been reduced from a mean of over 400 lbs. per acre to about 40 lbs. which means that nitric nitrogen enough for 360 lbs. of calcium and magnesium nitrates had disappeared from the surface foot of the corn and potato, or cultivated ground. After August 1, the nitrates of the surface foot rose very slowly until the corn was cut September 1, and then more rapidly until the soil contained about 100 instead of 40 lbs. per acre on September 18.

In the case of the not cultivated crops, clover, alfalfa and oats, the fields started April 18th with about 40 lbs. of nitrates per acre in the surface foot, which increased to nearly 70 lbs. on June 1st; from this date the nitrates fell somewhat rapidly until July 1, and then more slowly until August 1, when there was but little more than ten pounds per acre in the surface foot. By the end of August, however, the nitrates in the surface foot had become not far from 60 lbs. per acre.

In the case of the total soluble salts there was at first on the cultivated ground a more rapid rise in the surface foot from nearly 300 lbs. per acre on April 18, to about 500 lbs. on May 1, and reaching the highest point with the nitrates July 1st when the amount was 600 lbs. per acre. From this date there was a rapid decrease to nearly 250 lbs. August 1st.

Turning next to the not cultivated fields of clover, alfalfa and oats they start at the going out of the frost April 18, with about 250 lbs. of soluble salts per acre in the surface foot, but rise rapidly in 12 days to nearly 290 lbs. From this date there is a slow decrease until the time of maximum amounts in the cultivated soils, when there is only about 220 for the clover instead of 600 lbs. where corn and potatoes are growing. After the first of July the total salts in the surface foot remain stationary until August when they begin to rise, reaching about 250 lbs. September 1st, or the same as at the beginning of the season.

If comparison is made between the changes in nitrates in the

second, third and fourth feet and in the total soluble salts for corresponding depths it will be seen that the curves generally go through the same phases throughout the season under both the cultivated and not cultivated crops, each rising and falling together but through a much greater amplitude with the total salts where the amounts are so much larger.

The most striking difference between the seasonal changes, both of nitrates and total salts, in the first foot of soil, and in the next three feet, is found in the much greater fluctuations recorded for the surface.

RELATIVE AMOUNTS OF NITRATES AND TOTAL SOLUBLE SALTS IN FIELD SOILS.

The relation exisiting between the amount of nitric nitrogen in field soils computed as calcium and magnesium nitrates and the total soluble salts as indicated by the electrical resistance appears to be widely variable under different conditions.

As a general rule when the amounts of nitric nitrogen in clay loams are very high the total salts are relatively very low. It even happens that the electrical resistance will indicate but little more salts than are required to account for the nitric nitrogen computed as calciun and magnesium nitrates. Examples like the following are found:

Total solnble salts	182.1	186.6	338.9	313.
Nitric nitrogen as calcium nitrates	168.7	184.0	348.8	380.6

Results like these suggest that the electrical resistance fails signally to give the amounts of salts dissolved in the soil water. But in the absence of positive data as to just what salts may have been present with the nitrates in the above samples it does not appear impossible and perhaps not improbable that the nitrates were the only water soluble salts present. It is to be expected that if nitric acid is being formed in the presence of calcium and magnesium carbonates these would be decomposed to form the nitrates, and if the nitric acid was sufficiently abundant possibly no bicarbonates might remain in solution. If such cases do ever occur it is quite likely that the remaining water-soluble salts in our clay loams would be sufficiently small to leave the results consistent.

Again in the absence of evidence it may be anticipated that a strong solution of nitrates may be incompatible with the bicarbonates of lime and magnesia in the same solution, the strong nitrate solution, by physical action, causing precipitation just as the nitrates will cause flocculation of clays in turbid waters.

The ratio of total soluble salts to the nitrates in the surface foot of the five cultivated fields is, on the average for the whole season 2.14 to 1, while in the surface foot of the clover fields it is 4.8 to 1. For the 2nd, 3rd and 4th feet for the season the ratio is 7.29 to 1 for the corn and potato fields, and 9.97 to 1 for the clover, alfalfa and oats.

If the formation of nitrates in a soil does cause a destruction of the bicarbonates in the soil water some such ratios as are found should be expected.

RELATION OF THE AMOUNT OF NITRIC NITROGEN AND SOLUBLE SALTS IN FIELD SOILS TO THE CROP PRODUCED.

In the two plates, Figs. 30 and 31, pp. 220, 221, are plotted the amounts of nitric nitrogen as calcium and magnesium nitrates and the total salts found in the surface four feet of soil at eleven different dates during the growing season. We have an accurate determination of the yield of dry matter above ground in these cases, but have not yet determined the total nitrogen and ash removed in the crops.

It is clear from the curves plotted that marked differences existed in the amounts both of nitrates and of soluble salts in the soils. These differences are associated with marked differences of yield. On plot 9, where the nitrates did not reach 110 parts per million in the surface foot, the mean yield of dry matter per acre was 8,010 lbs., and the nitrogen removed was 102.11 lbs., computed from the tables in the Year Book, U. S. Dept. of Agriculture. Plot 3, where the nitrates were nearly 150 parts per million in the first foot, gave a yield of 11,440 lbs., of dry matter, and removing 146.05 lbs. of nitrogen, while Plot 1, with an amount of nitrates in the first foot at one time reaching nearly 210 lbs. per million, gave a yield of dry matter of 11,215 lbs. per acre and removed 139.88 lbs. of nitrogen.

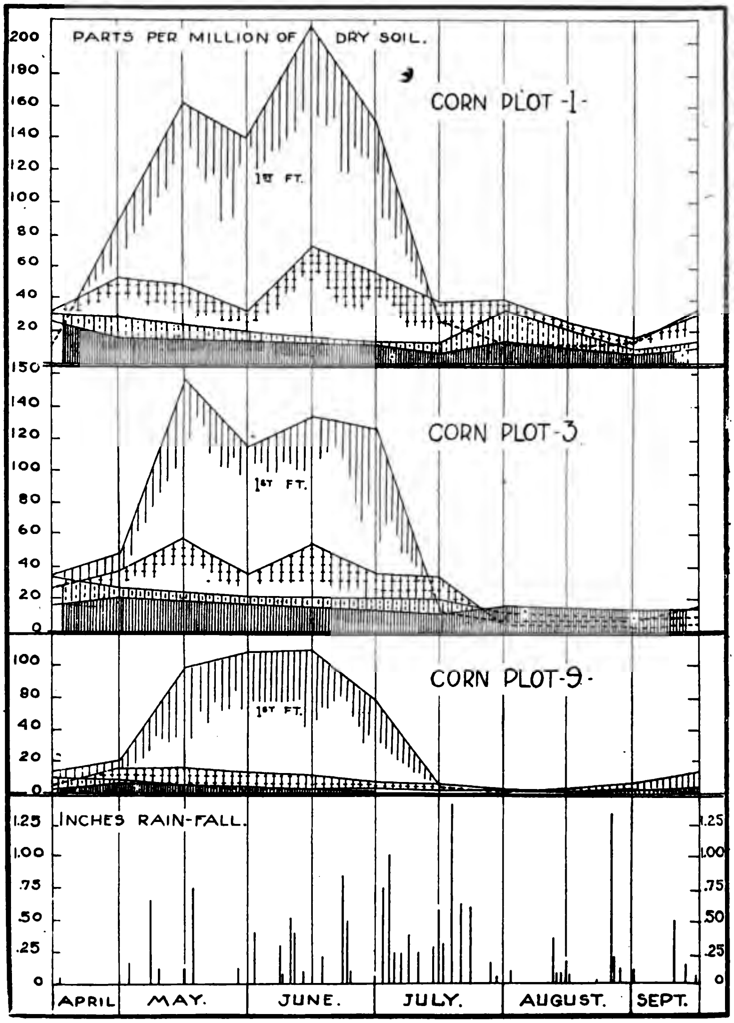

FIG. 30.—Showing changes in the amounts of calcium and magnesium nitrates during the growing season under three plots of corn.

In the case of these three fields of corn the largest yield was not associated with the soil having the highest per cent. of nitrates, either in the surface or lower feet. The heaviest yield is, however, associated with the largest amount of soluble salts as shown in Fig. 31.

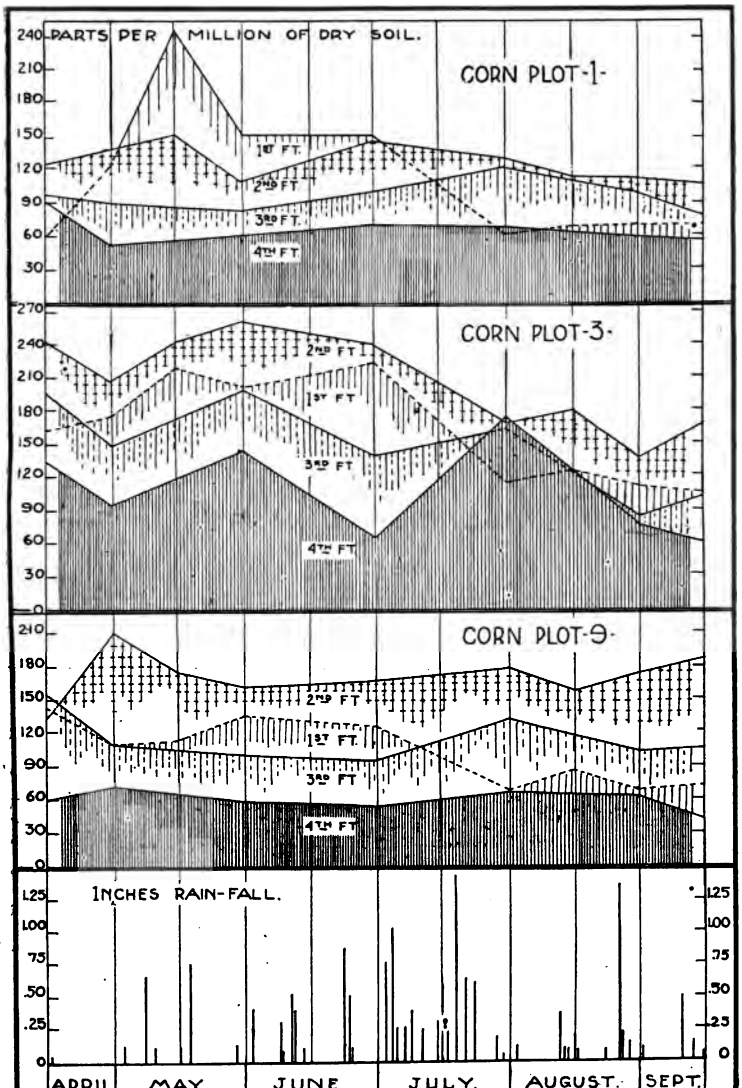

FIG. 31.—Showing the changes in the amount of total soluble salts as indicated by the electrical resistance during the growing season under three plots of corn. These curves are plotted on two-thirds the scale of that used for the nitrates.

In the case of the two clover plots and the plot of alfalfa the yields of dry matter per acre and nitrogen removed were

	Plot 2.	Plot 4.	Plot 7.	Plot 8.
Yield of dry matter............	5,839 lbs.	6,289 lbs.	8,151 lbs.	8,502 lbs.
Computed nitrogen removed. .	134.5	82.6	187.7	198.4

If we count the changes in the amounts of nitric nitrogen in the soil between the time when they were highest and when they were lowest as representing nitrogen taken by the crops the results will stand as below:

	Plot 1. Corn.	Plot 2. Clover.	Plot 3. Corn.	Plot 4. Oats and clover.	Plot 7. Clover.	Plot 8. Alfalfa.	Plot 9. Corn.
Nitrogen taken by crop	139.88	101.8	146.05	82.6	187.7	198.4	102.11
Nitrogen lost from soil...............	155.99	27.31	125.68	105.92	23.43	16.75	51.63
Difference......	-16.11	64.49	20.37	-23 32	164 27	182.67	50.48

From this table it appears that for the corn of plot 1 and for the oats and clover of plot 4 there was a loss of nitrogen from the soil greater than that computed as being removed by the crop; but in each of the other cases there has been a gain of nitrogen in the soil since the amount removed by the crop is greater than the change.

In the case of the three crops of alfalfa the nitrates were held so low at all times during the season that the soil shows a loss of only 16.73 lbs. and this makes it appear that there must have been formed in the soil during the season nitrates enough to supply the 182.67 lbs. additional needed, or else that the crop obtained it indirectly from the air. If it came from nitrates in the soil then there must have been formed, to supply the deficiency 1,004.69 lbs. of calcium and magnesium nitrates per acre. But referring to Fig. 32, it will be seen that both the total salts and the nitrates were lower at all times than under either of the other plots.

The nitrates and total salts in the soil of the two potato plots are represented in Fig. 33. The yield of plot 5 was 399.0 bushels per acre and of plot 6, 368.9 bushels.

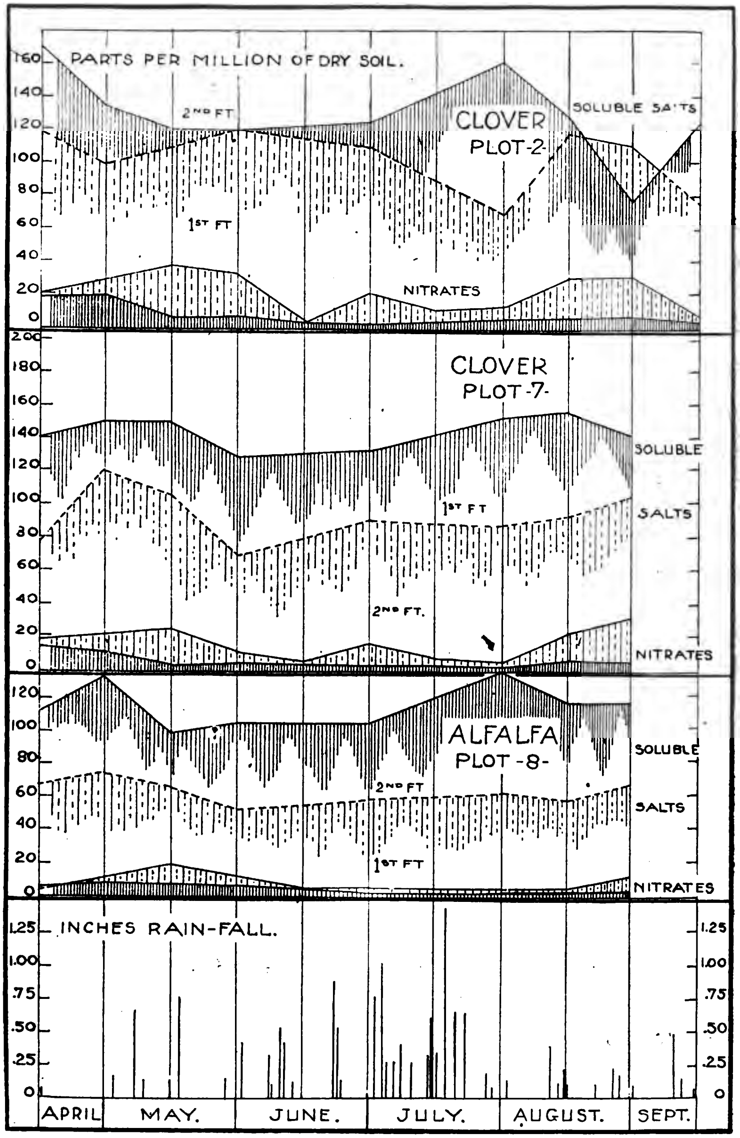

FIG. 32.—Showing changes in the amounts of nitrates and total soluble salts the first and second feet during the growing season under clover and alfalfa.

THE CLOSENESS WITH WHICH NITRATES ARE FED DOWN IN THE SOIL BY DIFFERENT CROPS.

One of the most surprising results to us which has been brought out by this season's work is the extremely small amounts of nitric nitrogen which may exist in a soil at any one time and yet vigorous plant grown and large yields be produced.

Referring to the curves it will be seen that the nitrates in the field were held down very low in the several feet during the 45 days following July 15. The amounts per acre are given in the table below:

Table showing the mean amouut of nitrates per acre under different crops between July 18 and Sept. 1.

	Corn. Plot 1.	Clover. Plot 2.	Corn. Plot 3.	Oats and clover. Plot 4.	Potatoes. Plot 5.	Potatoes. Plot 6.	Clover. Plot 7.	Alfalfa Plat 8.	Corn. Plot 9.
	Lbs. per acre.	Lbs per acre.	Lbs. per acre.	Lbs. per arce.	Lbs. per acre.	Lbs. per acre.	Lbs. per acre.	Lbs. per acre.	Lbs. per acre.
Nitrates in:									
1st foot.....	50.94	58.32	24.11	15.07	130.21	105.32	44.91	18.84	10.85
2d foot.....	127.35	23.74	48.81	14.42	155.95	172.62	15.63	10.65	8.88
3rd foot.....	83.52	10.28	59.44	18.81	49.65	50.66	1.75	9.53	10.79
4th foot.....	40.83	14.80	64.82	27.05	24.08	39.82	4.59	9:73	12.51

It will be seen from this table that with the right amount and distribution of water, such as we had this year, enormous yields may be produced when the nitrates in the surface foot of soil are as low as 24 lbs. for corn; 45 lbs. for clover; 19 lbs. for alfalfa and 105 lbs. for potatoes per acre.

When these amounts are expressed as nitric nitrogen in parts per million of the dry soil they stand 3.35, 1.61 and 0.72 for corn; 3.87, 2.98 and 1.00 for clover; 1.25 for alfalfa and 8.64 and 6.99 for potatoes.

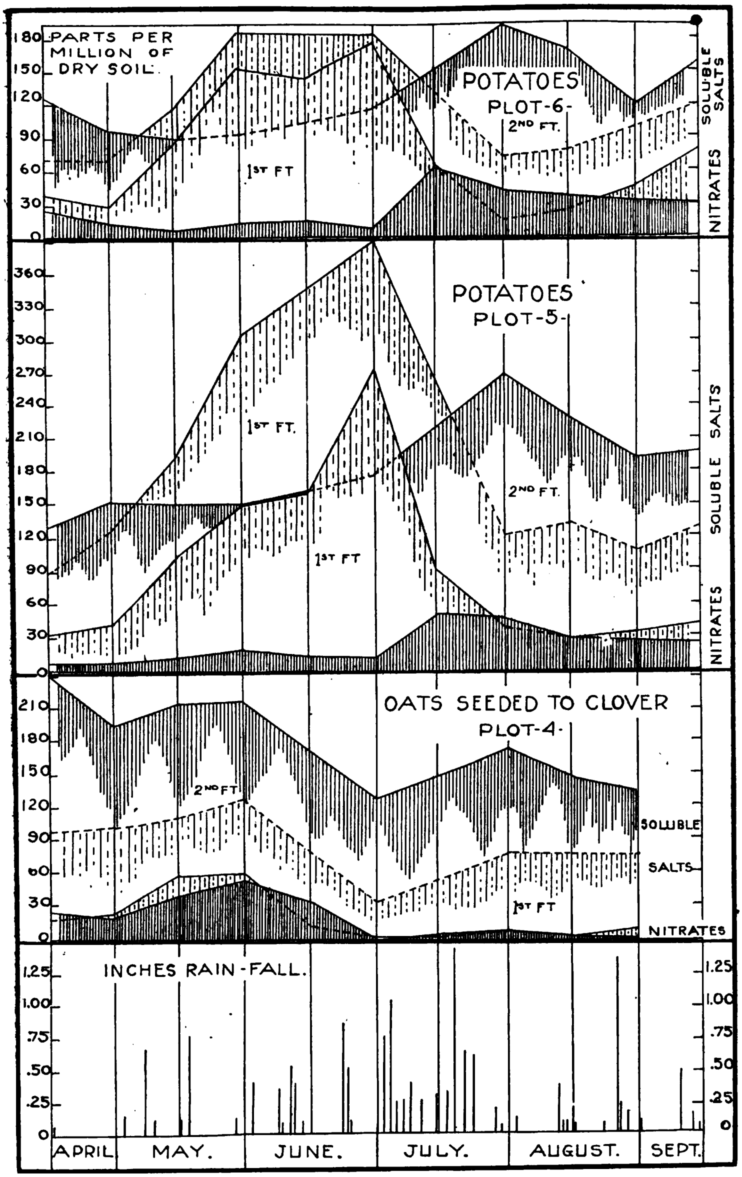

FIG. 33.—Showing the changes in the amounts of nitrates and of total soluble salts in the first and second feet during the growing season under potatoes, and oats seeded to clover.

The following subjects have ben investigated and the data prepared for this paper, but lack of space prevents their presentation here and they may appear later as a bulletin:

"The Limit of Nitric Nitrogen in Field Soil at Which the Leaves of Corn and Oats Turn Yellow;" Difference Between the Amounts of Nitric Nitrogen Under Growing Crops and in Cultivated Fallow Ground at the Same Time;" "Distribution of Nitrates and Other Soluble Salts in Soil Under Growing Corn as It Comes into Full Tassel;" "Methods of Determining Soluble Salts and Nitric Nitrogen in Field Soils."

EXPERIMENTS WITH GRAIN AND FORAGE CROPS.

R. A. MOORE.

I. VARIETY TESTS OF GRAIN.

The variety tests of grain and forage crops for 1900 are a continuation, on a more extensive scale, of those conducted in 1899.

The object sought in these tests is to secure varieties of grain that are hardy and productive, and by careful selection and culture to improve upon these qualities until we have found out which varieties of these various kinds of grains produce the best results under our conditions. Samples of these standard varieties will then be sent to former students and others interested in progressive agriculture for further trials. This year experiments with rape, clover and oats were carried on by former students in different localities with interesting and valuable results. This work will be emphasized in the future so as to get results from all portions of the state for comparison.

The seed grain used for our experiments this year was either raised in 1899 on the experimental farm, or secured from the Ontario (Canada), Minnesota, and Iowa Experiment Stations, or the United States Department of Agriculture. A few samples were purchased of the Salzer Seed Co., La Crosse, Wis. The seed secured from the various experiment stations and the United States Department of Agriculture was donated and was of varieties that through a series of tests had proved hardy and productive in their respective localities.

The field in which the plot work on the Experiment Station farm was conducted contains about five acres and is light clay loam. The preceding year it had been treated to a coating of

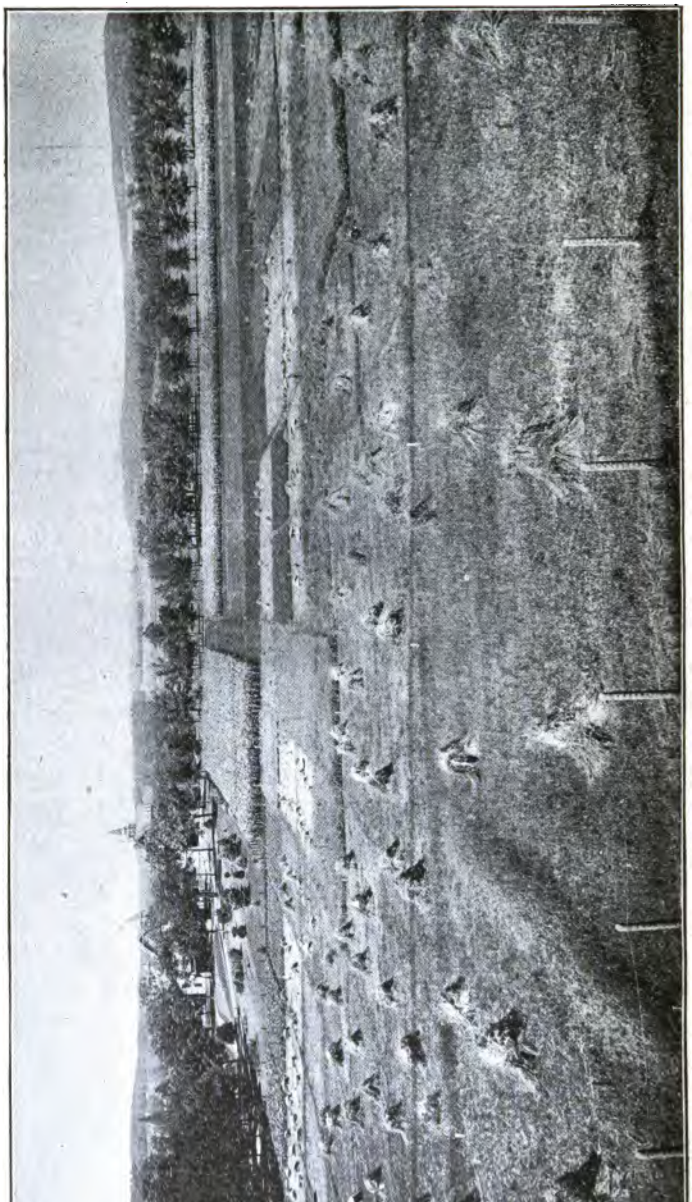

FIG. 35.—Experiment plots, 1900.

barn-yard manure and planted to corn. It was plowed in the fall and left bare during the winter. As soon as it was sufficiently dry in the spring it was worked with disc harrow and pulverizer until the seed bed was properly prepared. The seed was sown broadcast on rectangular plots, varying from one square rod to one-eighth of an acre, and harrowed twice with light harrow.

For tests of hardiness and productiveness the following number of varieties of various kinds of grain were sown: oats 33, barley 15, spring wheat 10, peas 6, spelz 2, and spring rye 1. Approximately, 150 bushels of seed grain were raised on the whole field, which will be retained for further trials. For convenience all varieties of grain have been given a Wisconsin inventory number and will be known by that number hereafter. The yield of grain and other data connected with the variety tests are given in the following table:

Yield of straw and grain in variety tests of cereals, 1900.

Name of Variety.	Wisconsin No.	Seed grain received from	Date of sowing.	Seed per acre (by weight).		No. of days reaching maturity.	Yield per Acre.		Weight of grain per measured bushel.
							Grain (by weight).	Straw.	
Oats.			1900.	Bu.	Pks.		Bu.	Tons.	Lbs.
Siberian	1	Wis. Exp. Station	Apr. 23	3		93	51.1	1.9	37
Daubenney	2	Wis. Exp. Station	Apr. 23	3		81	40.	2.	30
Poland White	3	Wis. Exp. Station	Apr. 23	3		93	59.1	2.	37
Swedish Oats	4	Wis. Exp. Station	Apr. 23	3		95	64.5	2.5	37
Two-foot Long	5	Salzer Seed Co.	Apr. 30	3		91	76.	2.	34
Tabolsk	6	Wis. Exp. Station	Apr. 23	3		95	55.3	2.3	38
Golden Sheaf	7	Minn. Exp. Station	Apr. 24	3		98	54.	2.	35
Early Gothland	8	Minn. Exp. Station	Apr. 24	3		91	50.2	1.9	36
Minnesota	9	Minn. Exp. Station	Apr. 24	2	3	96	61.	2.7	36
White Russian	10	U. S. Dept. of Agri	Apr. 24	2	3	99	45.1	2.6	34
Ohio Early Ripe	11	U. S. Dept. of Agri	Apr. 24	3		81	27.0	1.2	30
Big 4 Oats	12	Salzer Seed Co.	Apr. 24	2	3	95	76.4	2.3	34
Bow of Promise	13	Salzer Seed Co.	Apr. 24	2	3	95	79.2	2.5	35
Burls Early Red Rust Proof	14	Minn. Exp. Station	Apr. 24	2	3	95	43.1	2.	33
Lincoln	15	Minn. Exp. Station	Apr. 24	2	3	96	58 6	2.3	34
Monarch	16	Minn. Exp. Station	Apr. 24	2	3	95	59.	2.4	36
White Bedford	17	Minn. Exp. Station	Apr. 24	2	3	94	34.	1.5	36
Archangel	18	Minn. Exp. Station	Apr. 24	2	3	95	52.5	2.	36
Black Hungarian	19	U. S. Dept. of Agril	Apr. 24	3		Did not mature			
Texas Rust Proof	20	U. S. Dept. of Agri	Apr. 26	3		100	47.9	2.5	31
White Wonder	21	Minn. Exp. Station	Apr. 26	3		91	39.3	2.5	35
Improved Ligowa	22	Minn. Exp. Station	Apr. 26	3		91	61.2	2.2	35
Zhelaznii	24	Wis. Exp. Station	Apr. 26	3		91	53.5	2.1	34
Si ver Mine	25	Wisconsin	Apr. 28	3		90	70.4	2.	36
Iowa Silver Mine	26	Iowa Exp. Station	Apr. 28	1		88	50.	1.4	38
Black Russian	27	Iowa Exp. Station	Apr. 28	1		88	30.	1.7	35
White Belgian	28	Iowa Exp. Station	Cpr. 28	1		88	38.	1.6	36
Red Rust Proof	29	Iowa Exp. Station	Apr. 28	4		88	39.	1.5	36
Early Dawson	30	Iowa Exp. Station	Apr. 28	1		88	32.4	1.	40
Neb. Gold Mine	31	Iowa Exp. Station	Apr. 28	1		88	46.5	1.5	35
Clydesdale	32	Iowa Exp. Station	Apr. 28	1		82	44.	1.2	38
Early Champion	33	Iowa Exp. Station	Apr. 28	1		82	17.	1.1	33

BARLEY.									
Beardless	51	Salzer Seed Co	Apr. 27	1	2	87	50.7	1.5	42
Sisolsk	52	Wis. Exp. Station	Apr 27	1	2	78	38.	2.	46
Silver King	53	Salzer Seed Co	Apr. 27	1	2	78	61.	1.5	46
Mandshury	54	Wis. Exp. Station	Apr. 27	1	2	78	55.3	1.8	48
Oderbrucker	55	Wis. Exp. Station	Apr. 27	1	2	83	56.4	1.4	47
Kinna Kulla	57	Wis. Exp. Station	Apr. 27	1	2	86	47.1	1.5	47
French Chevalier	60	Minn. Exp. Station	Apr. 27	1	2	86	49.	1.9	45
Golden Queen	61	Minn. Exp. Station	Apr. 27	1	2	85	58.6	1.6	46
Mandschuri	62	Wis. Exp. Station	Apr. 27	1	2	85	59.2	1.6	48
Bernardo	63	Minn. Exp. Station	Apr. 27	1	2	83	56.7	1.8	49
Manshury	64	Minn. Exp. Station	Apr. 37	1	2	85	56.3	1.6	47
Giant White Hulless	65	Salzer Seed Co	Apr. 27	1	2	85	61.8	1.4	55
SPRING WHEAT.									
McKendry's Fife	101	Minn. Exp. Station	Apr. 25	1	3	89	28.	1.7	60
Power's Fife	102	Minn. Exp. Station	Apr. 25	1	3	94	28.	1.6	54
Risting's Fife	103	Minn. Exp. Station	Apr. 25	1	3	94	27.3	1.7	57
Glyndon	104	Minn. Exp. Station	Apr. 25	1	3	94	28.	1.7	54
Advance	105	Minn. Exp. Station	Apr. 25	1	3	87	28.7	1.9	61
Haynes Blue Stem	106	Minn. Exp. Station	Apr. 25	1	3	94	27.3	1.7	58
Preston	107	Minn. Exp. Station	Apr. 25	1	3	94	28.	2.	58
Ballous Blue Stem	108	Minn. Exp. Station	Apr. 25	1	3	94	29.4	2.6	57
Wellman's Fife	109	Minn. Exp. Station	Apr. 25	1	3	94	34.7	2.5	59
Herison	110	Ontario Station	Apr. 27	1	3	87	27.1	2.5	57
PEAS.									
Oddfellow	141	Ontario Exp. Station	Apr. 26	1	3	100	29.6	1.5	65
Early Britain	142	Ontario Exp. Station	Apr 26	1	3	92	30.4	1.4	58
White Wonder	143	Ontario Exp. Station	Apr. 26	1	3	92	36.2	1.4	63
Prussian Blue	144	Ontario Exp. Station	Apr. 26	1	3	96	44.	2.1	62
Gray Winter Field	145	U. S. Dept. of Agri	Apr 28	2		100	35.	.6	56
Gray Spring Field	146	U. S. Dept. of Agri	Apr. 28	2		100	11.	1.	57
SPELZ.									
Russian	121	Wis. Exp. Station	Apr. 26	1		95	30.	1.4	44
Salzers	122	Salzer Seed Co	Apr. 26	1		95	32.2	1.7	48
SPRING RYE.									
Prolific	131	Salzer Seed Co	Apr. 26	1	3	90	36.1	1.9	56

CONCLUSIONS.

Of the *oats* tested for two successive years the Swedish, Poland White and Tobolsk gave the best returns and appear most satisfactory for this state; of the *barley* the Oderbrucker and Mandshury varieties seem best adapted to our conditions. Some of the new varieties gave better returns than the above mentioned, but as it is characteristic of some varieties of grain to give good returns the first year sown in a locality and later to lose their vitality, further mention will be reserved until another trial is given them.

The *spelz* gave better returns this year than last and was more satisfactory in every way. Spelz is a plant that stools strongly; a sample of the grain taken from the growing plot showed 34 stalks with fully developed heads growing from a single kernel. The land is prepared in the same manner as for spring wheat or oats, and the seed grain sown broadcast or with drill, one and one-fourth bushels per acre. Spelz is said to grow on any soil where rye can be grown, and is noted for its strength to resist drought. As a food for fattening stock it is claimed to rank with the foremost cereals. The heads were short and the yield of grain per acre was not as large as that secured from barley. The wonderful stooling qualities of the spelz and rapidity of growth will probably make it a good soiling crop.

The *peas* sown produced an excellent growth of vines and pods and the yields were very satisfactory, but the ravages of the pea weevil make them a very uncertain crop in this locality. The lakeshore counties north of Milwaukee seem to be the natural pea-growing centers of Wisconsin, where peas can be grown without injury from the weevil. No less than 25 per cent. of the peas grown in these experiments were affected with weevil.

The several varieties of barley listed as Manshury, Mandshury and Mandschuri were grown under similar conditions and no difference could be detected at any period of the growth between the varieties. The threshed grain was similar and the facts seem to show that in all probability all these are the same variety of barley. The others have originated from the various spellings of the name Mandschurei, the country from which the barley originated.

Thick and thin seeding of oats.—In an experiment with thick and thin seeding of oats to note the effect on the yield and the tendency to lodge, no appreciable difference was observed where the grain was sown from 2½ to 3½ bushels per acre. All plots lodged quite badly, and the yields obtained varied only a trifle. In no case where oats were seeded one bushel per acre did they lodge, although severe storms occurred. Of eight varieties tested on plots where oats were sown at the rate of 1 bushel per acre, the average yield was 37 bushels per acre, weighing 36.4 pounds per measured bushel. The grain and straw were of a superior quality. Farmers having very rich soil where crops have a tendency to lodge, may, according to our experience this year, prevent the lodging materially by using one-half the ordinary amount of seed and thereby get a superior quality of grain.

Treating seed oats to prevent smut.—The seed grain was reserved from a field that had been slightly affected by smut the previous year. A plot containing 1-20 of an acre was sown from the sample without treatment, while an equal area was sown with seed treated as prescribed by Professor Goff, as follows: "Saturate the seed oats with a solution made by adding one pound of formalin to 50 gallons of water. To use the remedy, place a layer of oats four inches thick on the floor and sprinkle them with the formalin solution until they are entirely wet; then another layer may be placed on top of the first layer and sprinkled as before, repeating the process until all the seed oats have been sprinkled; then leave them in the pile for two hours, when they should be spread out thinly to dry. They should be shoveled over once or twice a day until dry. One pound of formalin will treat 50 bushels of oats and can be purchased at most any drug store at about 60 cents per pound." Where only a few bushels are to be treated, the solution is made as above outlined, putting the same in a cask. The oats are placed in a gunny sack and immersed in the solution for 20 minutes, and after draining they are spread out to dry.

The seed oats used in this experiment were treated in accordance with the latter method.

The oats grown on the plot where the seed was not treated had

five per cent. of the heads affected with smut. This estimate is the average of several careful counts made on small areas while the grain was growing. On the plot where the seed oats were treated to prevent smut, not a single head could be found during the growing period that was affected in the least with smut; the treatment was therefore in this case found to be absolutely effective.

II. NOTES ON FORAGE PLANTS.

Vetch as a forage plant.—Two varieties of vetch were used in this experiment, the *Sand* or *Hairy* vetch and the *Spring* vetch. In each case plots containing 1-20 of an acre were sown at the rate of one bushel per acre. One month after seeding there was a luxuriant growth of vines, and the vetches looked promising, but Blister beetles attacked the plants while in blossom and nearly ruined the crop.

The *Sand* vetch lodged badly and was cut for hay, producing 3½ tons cured hay per acre; the *Spring* vetch was left to ripen and yielded two bushels of seed per acre, weighing 62 pounds per measured bushel.

As a forage plant vetches are in the experimental stage under the conditions present in this state; stock do not relish green vetches and eat them very sparingly when cured for hay. The vetch is a leguminous plant and is said to be a great nitrogen-gatherer. Its chief use may be as a restorer for the soil nitrogen; experiments will be carried further by the Station with that end in view.

Victoria versus Dwarf–Essex rape.—The superior qualities of the Victoria rape having been brought to the attention of the Experiment Station, two trials were made at different periods to determine wherein it differed from the Dwarf–Essex in point of excellence.

In the first trial two plots, each containing 1-20 of an acre, were sown on April 30th to Dwarf–Essex and to Victoria rape, the seed being put in in drills 28 inches apart, at the rate of four pounds of seed per acre. The seed germinated at the same time, and no difference could be noticed at any time during the growing period in the general characteristics of the plants. The

plots were cut July 12; the weight of green forage was slightly in favor of the Dwarf-Essex, it yielding at the rate of 19.3 tons of green forage per acre, while the Victoria yielded 18 tons per acre.

In the second trial the rape was sown as above described on May 31st, and was cut for green forage on Aug. 4th. No characteristic difference could be noted between the two varieties at any period during the growth, but the yield was again in favor of the Dwarf-Essex, which produced at the rate of 19.7 tons of green forage per acre, and Victoria 18 tons per acre. It would seem from these trials that we have as yet only one standard variety of forage rape, and that is the Dwarf-Essex; the other so-called variety probably being the same plant with a different name.

It was noted in the above experiment that where very dry weather continues after cutting rape, no second growth will make its appearance, but if atmosphere is cool and sufficient moisture in the soil the rape sprouts out readily and makes a fine fall pasture for cows, pigs, or sheep.

Rape sown with oats at the time of seeding, and two weeks thereafter.—The object of the experiment was to determine whether a good catch of rape could be secured that would not seriously interfere with the growth of oats and produce good fall pasture. Two adjoining plots, containing 1-20 of an acre each, were sown to oats at the rate of three bushels per acre, and harrowedin in the regular way; on one plot rape was sown broadcast the same day of seeding oats, at the rate of five pounds per acre, and covered by running a slant-tooth harrow once over the field. Two weeks later, after the oats on the adjoining plot were three inches above ground, rape was sown thereon at the rate of five pounds per acre and dragged once with a slant-tooth harrow. The dragging seemed to materially injure the oats, from which they did not fully recover; and when rape plants did appear above ground they were so densely shaded that their growth was very slow and many withered and died.

On the plot where the rape was sown on the same day of seeding oats the rape plants appeared very shortly after the oats were above ground, and did not seem to interfere with the

growth of oats until the latter part of the growing period, when the rape apparently hindered somewhat the ripening of the oats and consequently delayed the maturing period about one week beyond that of other plots of the same variety sown with oats exclusively, and the yield of grain was reduced about one-fifth. The plot where rape was sown two weeks later than the oats yielded at the rate of 60.3 bushels of oats per acre; the plot where the rape was seeded on the same day yielded at the rate of 50.3 bushels of oats per acre. The same variety of oats on plots where no rape was sown gave a yield at the rate of 64.5 bushels per acre. The rape prevented the oats from lodging, consequently a fine grade of oats was secured. The green rape prevented the oats from drying readily, thus making it necessary to leave them in the field several days beyond the time of hauling oats grown without rape that were cut at the same time. Where rape is sown with oats, the latter should be cut, so as to leave the stubble as high as possible. By cutting in that way only the upper leaves of the green rape would be bound with the oats, and these would dry quite readily.

On the plot where rape was seeded on the same day of seeding oats the stand of rape was excellent four weeks after cutting the oats, and an abundant amount of fall fodder was secured.

Experiments in clover seeding.—In this experiment clover was sown in three different ways, viz.: 1, with oats as a nurse crop; 2, with oats that were cut for hay while green; 3, seeded without a nurse crop. Wisconsin No. 4 oats and Mammoth and Medium Red clover were used on duplicate plots, the oats being sown at the rate of three bushels per acre, and clover at the rate of ten quarts per acre.

On the plots where oats were left to ripen the clover was quite thin, and of a pale color at the time of cutting the oats. Frequent showers occurred after cutting the oats which caused the clover to stool more strongly and to give a fair appearance. On the plots where oats were cut for hay the clover grew rapidly as soon as the oats were removed, and in three weeks cut at the rate of nine-tenths of a ton cured hay per acre for each variety of clover. The oats averaged 2½ tons of cured hay per acre. On the plots where clover was seeded without a nurse crop the

ground was prepared in the regular way for an oat crop, and the clover was sown broadcast at the rate of ten quarts per acre. A slant-tooth harrow was run over the ground once, so as not to cover the seed too deeply. The ground was clean and very little difficulty was experienced with weeds; the clover got a good start before any weeds made their appearance. It grew rapidly, and on August 1st the Mammoth clover cut 1.2 and the Medium Red clover 1.3 tons per acre. Another good cutting could have been taken from the plots, if desired. The stand September 1st is excellent; all plants look strong and healthy.

From the reports of former students on seeding clover without a nurse crop the weeds seem to be the chief difficulty; it seems therefore advisable not to sow clover alone on very weedy ground, but to sow with oats as a nurse crop and cut the oats for hay shortly after heading, if the season is dry. In this way the oats shade the weeds to such an extent that they are kept down, and after the oats are cut the clover spreads its leaves above the weeds and soon gains the ascendency.

Where clover is sown without a nurse crop and weeds make their appearance, the mower should be run over the field with the cutter bar set at such a height as to cut the tops of the weeds; the clover will then spread out over the weeds and hinder their growth. The process is repeated, if necessary.

The difficulty in getting the catch of clover seems to be due mainly to a lack of moisture; in a wet season a good stand will be secured by sowing clover in the ordinary way with oats as a nurse crop. If the season is dry the oats can be cut while green for hay, before drought has injured the clover to such an extent as to prevent the catch.

In the preceding experiment where the oats were cut for hay, the stand of clover was much better than on plots where oats were left to ripen.

Soy Beans.—The Soy Bean is cultivated with success in the south, but in the north it is still in the experimental stage. Like the clover, the Soy Bean is a nitrogen gatherer and enriches the soil on which it grows. Stock eat the green plants with great relish and also the cured hay. The leaves break off readily when dry, making it difficult to handle, and the loss of forage is com-

paratively great where the object is to cut and cure the Soy Beans for hay. In Japan the Soy Bean is extensively used as food for men and animals.

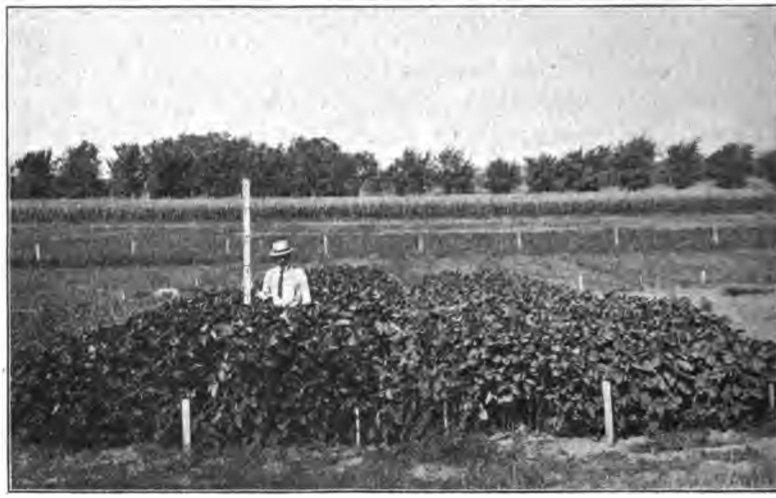

FIG. 36.—Soy beans.

In the experiment carried out, three varities, the *Black, Yellow* and *Green* Soy Bean were used. The ground was prepared in the ordinary way for field crops, and the beans sown broadcast at the rate of 2½ bushels per acre, April 28th. The beans made a rapid growth, and on August 7th two varieties measured four feet in height; a portion of the Green variety was cut for forage and showed a cutting of 9.9 tons green feed per acre.

The Black and the Green beans ripened and produced fully matured seed, but the other variety produced pods, while the seed did not reach maturity. The experiment will be continued another year in order to determine more fully the value of the Soy Bean as a nitrogen gatherer and a forage plant in this locality.

SUGAR BEET CULTURE IN WISCONSIN DURING 1899.

F. W. WOLL.

The study of problems connected with the culture of sugar beets in Wisconsin, which was commenced by this Station in 1890, was continued during the last year, according to a similar plan as in previous years. In reporting the results of last year's work in this line, the co-operative trials with sugar beets conducted by Wisconsin farmers under the direction of the writer will be described first, and an account will then be given of the experiments with sugar beets at our Experiment Station farm.

A. ANALYSES OF SUGAR BEETS GROWN BY FARMERS IN DIFFERENT PARTS OF THE STATE.

The effort was made in distributing sugar beet seed for trial purposes during last season to secure the co-operation of a number of careful and interested farmers in such parts of the state where rich beets have been grown in previous years, and miscellaneous applicants were furnished with a small amount of seed upon request only. Complete directions for growing and harvesting the crop, as well as for taking analysis samples of the beets, were sent each farmer with the seed. One hundred ninety-seven farmers in all were supplied with high-grade imported sugar beet seed in the spring, varying in amounts from one-half to five pounds each.

Character of the season.—The season of 1899 was, as a whole, favorable to crops in this state, the average rainfall for April to September being nearly two inches above normal, and the average temperature four degrees Fahr. above normal. The precipitation for the months of April to October for thirty-five weather stations in this state will be seen from the following table, the data having been obtained from the published records of the Wisconsin Section of the Climate and Crop Service of the United States Weather Bureau, W. S. Wilson, Section Director.

Precipitation, April to October, 1899, in inches.

Name of station.	County.	Elevation.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total Apr.—Sept.
Barron	Barron	1,115	1.73	3.15	......	......	5.87	.65	4.26	......
Green Bay	Brown	616	3.15	1.95	4.85	4.99	.36	2.16	1.35	17.46
Grantsburg	Burnett	1,100	2.30	5.97	2.30	2.08	4.89	1.63	4.63	19.37
Chilton	Calumet	926	1.90	3.40	[1]5.72	2.64	2.22	2.85	......	......
Neillsville	Clark	600	2.18	5.14	7.32	2.61	2.76	1.05	3.52	21.06
Portage	Columbia	809	2.02	4.02	8.97	2.57	2.58	2.85	1.52	23.01
Prairie du Chien	Crawford	690	1.78	3.93	7.23	1.41	3.00	1.56	2.08	17.91
Madison	Dane	955	2.69	4.92	2.64	3.22	3.57	3.35	1.58	20.39
Duluth, Minn	[Douglas]	670	1.33	4.66	7.10	1.82	6.18	2.05	3.54	23.14
Knapp	Dunn	......	1.60	5.87	8.37	......	4.91	3.42	4.45	......
Eau Claire	Eau Claire	600	1.58	8.47	7.02	1.62	7.67	3.23	3.61	29.59
North Crandon	Forest	1,100	......	......	1.60	.90	3.12	5.92	6.40	......
Lancaster	Grant	1,070	2.51	5.25	5.82	4.94	4.18	.93	1.68	23.66
Dodgeville	Iowa	1,116	3.56	4.64	4.99	2.31	2.77	1.44	1.48	19.71
Watertown	Jefferson	......	2.32	4.82	4.39	3.72	3.85	3.01	2.14	22.11
Lincoln	Kewaunee	817	2.32	1.08	6.48	6.14	1.00	2.63	1.48	19.65
La Crosse	La Crosse	714	2.88	4.58	11.56	4.10	3.72	1.06	1.11	27.90
Heafford Jct	Lincoln	......	2.47	4.66	4.96	2.35	4.77	2.07	3.85	21.28
Manitowoc	Manitowoc	616	1.67	3.07	2.76	3.40	.93	2.35	1.42	14.18
Wausau	Marathon	1,212	4.26	4.43	6.77	2.96	2.58	2.28	3.27	23.28
Westfield	Marquette	925	1.56	4.77	6.38	1.86	3.98	2.13	1.29	20.67
Milwaukee	Milwaukee	673	.68	3.42	2.29	2.56	2.54	3.04	1.21	14.53
Valley Jct	Monroe	......	3.41	4.82	7.39	2.19	3.39	1.60	1.04	22.80
Oconto	Oconto	590	[2]2.53	2.76	4.08	5.70	3.38	1.14	1.13	19.59
New London	Outagamie	763	2.89	3.15	7.07	6.50	.88	2.31	2.24	23.80
Port Washington	Ozaukee	717	1.68	3.48	2.42	3.82	1.20	3.75	1.80	16.35
Prentice	Price	......	2.57	7.17	7.75	3.07	7.40	[3]3.47	5.56	31.43
Racine	Racine	633	.31	4.89	3.17	4.26	1.08	4.25	1.34	17.96
Beloit	Rock	750	2.65	6.15	2.63	4.02	2.49	3.30	1.50	21.14
St. Paul, Minn	[St. Croix]	831	1.35	3.50	7.23	1.51	2.80	1.21	3.09	17.60
Whitehall	Tremp'leau	675	1.12	4.34	7.64	1.60	4.91	2.94	2.35	22.55
Delavan	Walworth	920	1.55	5.16	2.52	2.98	2.52	2.75	......	......
Hartford city	Washingt'n	1,017	1.61	5.81	2.77	3.65	3.43	2.99	2.52	20.26
Waukesha	Waukesha	970	1.19	3.92	3.99	2.14	2.50	3.18	1.21	16.92
Oshkosh	Winnebago	744	3.50	2.77	......	2.15	1.50	2.02	1.22	......
Average for state		......	2.42	4.21	5.54	3.19	3.27	2.57	2.50	21.20
Normal for state		......	2.65	3.81	4.19	3.06	2.58	3.05	2.42	19.34
No. of rainy days for state		......	......	10	10	......	8	7	7	......
Mean temperature for state		......	47.2	55.8	66.1	70.3	70.5	57.3	52.1	61.2
Normal temperature for state		......	45.1	54.9	66.3	70.4	67.9	60.5	48.5	60.8

[1] Record for 26 days. [2] Record for 23 days. [3] Record for 29 days.

The temperature conditions during the season were, as will be seen, fairly equable. The greatest departures from the normal occurred in April, August and September, the average temperature for April and August being over two degrees higher than the normal, while the September average was over three degrees below normal. The total precipitation for the growing season was 21.20 inches on the average; April and September show a slight deficit, while from May to August the rainfall was in excess of the monthly normals. Although the monthly rainfall for the state during the month of August was above the average, a local drought of considerable severity developed during the latter part of the month in the extreme southeastern counties and along the lake, causing some damage to late crops. There is but little doubt that the drought in August in this portion of the

state considerably reduced the yields of beets obtained and hastened the maturity of the beets.

The analyses made in the fall include 178 samples of beets grown in 56 counties of the state. The average results of the analyses of the sugar beets forwarded for examination in the fall are shown in the following table, the samples being arranged under the counties in which they were grown:

Compilation of results of sugar beet analyses in Wisconsin, 1899.
(Arranged by counties.)

County.	No. of samples.	Aver. size of topped beets.	Sugar in juice.	Purity of juice.	Yield per acre.
		Lbs.	Per cent.	Per cent.	Tons.
Adams	1	1.1	15.66	83.2	10.0
Barron	1	1.0	14.91	80.5	....
Brown	13	1.5	14.44	80.8	[1]15 0 (6)
Buffalo	2	1.5	16.74	86.1	20.0 (2)
Burnett	1	0.7	18.85	83.6	11.5
Calumet	4	1.3	13.60	75.0	20.0 (2)
Chippewa	1	.8	15.01	79.1	....
Clark	2	1.2	14.11	78.6	7 0 (1)
Columbia	4	1.3	13.09	76.7	12.2 (1)
Crawford	5	1.4	13.16	80.4	15.1 (2)
Dane	11	1.2	14.21	77.4	21.8 (2)
Dodge	2	1.2	15.35	80.9	15.0 (1)
Door	1	1.8	16.48	83.0	13.8
Douglas	1	0.6	15.93	86.4	....
Dunn	4	1.3	13.60	77.7	24.0 (2)
Fond du Lac	1	1.2	12.12	75.1	....
Green	1	1.4	9.46	69.7	24.0
Green Lake	1	1.4	14.62	82.2	....
Jackson	3	.8	16.51	86.4	....
Jefferson	4	1.5	14.22	79.5	....
Juneau	1	3.2	14.35	83.4	....
Kenosha	2	1.0	15.78	81.4	25.2 (1)
Kewaunee	8	1.5	15.50	79.8	10.8 (1)
La Crosse	2	1.0	13.81	77.0	14.0 (1)
La Fayette	1	1.3	14.59	74.2	....
Lincoln	1	.9	16.48	84.6	....
Manitowoc	5	1.3	15.17	82.5	18.0 (1)
Marathon	5	.8	14.46	81.8	....
Marinette	2	2.1	13.42	78.1	....
Marquette	4	1.0	15.73	80.7	16.5 (1)
Milwaukee	1	.8	19.78	87.8	....
Monroe	3	1.3	14.24	77.8	....
Oconto	6	1.5	14.09	81.7	8.0 (1)
Oneida	1	1.4	13.63	76.9	15.0
Outagamie	8	1.4	15.63	83.0	22 0 (1)
Ozaukee	1	2.0	14.34	82.4	....
Pepin	1	1.0	19.60	83.5	....
Polk	3	1.4	14.45	83.1	10.0 (1)
Portage	2	1.7	13.16	80.5	....
Price	2	1.5	13.64	77.0	....
Racine	2	1.9	15.23	79.5	....
Rock	3	1.0	15.73	79.1	....
St. Croix	3	1.2	13.25	76.9	....
Sauk	7	1.0	15.15	79.1	11.0 (1)
Shawano	1	.9	17.33	85.4	....
Sheboygan	1	2.0	18.09	84.7	....
Taylor	1	1.0	15.40	80.2	....
Vilas	1	1.4	16.85	85.4	....
Walworth	2	1.6	13.42	76.9	16.5 (1)
Washburn	2	1.9	13.05	77.6	20.0 (1)
Washington	2	2.1	17.50	84.7	....
Waukesha	7	1.3	16.09	84.3	15 7 (2)
Waupaca	9	1.7	13.80	79.3	12.0 (1)
Waushara	7	1.1	15.90	83.1	16.2 (1)
Winnebago	2	2.2	14.04	80.1	....
Wood	1	1.7	12.57	74.4	....
Unidentified	5	.9	14.25	75.4	....
Averages for 56 counties	178	1.34	14.68	80.5	16.1 (39)

[1] Average of 6 reports.

The average weight of the topped beets was 1.34 lbs., the average per cent. of sugar in the juice 14.68 (equal to 13.95 per cent. sugar in the beet), purity of juice 80.5 per cent., and the average yield of beets per acre reported by 39 farmers, 16.1 tons. This would show an average yield of sugar per acre of about 4,216 lbs. If the average data given are compared with those of previous years it will be seen that this year's results show a marked improvement in both content of sugar and purity of juice. The main reason for this improvement must be sought in the fact that a majority of the farmers who co-operated with the Station in this work during last year were interested in the culture of sugar beets and had had previous experience in growing the crop, and the number of farmers who did not give proper attention to preparing the soil or keeping the beet plat free from weeds was relatively small. As stated in the introduction, seed was furthermore distributed mainly in the counties that have been found to produce rich beets, by which method the averages for the whole state were, of course, raised.

Rather than discussing the results of last year's analyses only, of beets grown in different counties of the state, it was decided to compile all analyses made of Wisconsin-grown beets since this investigation began in 1890, and to study the average data thus obtained. The following table presents the summary results for the six years between 1890 and 1899, during which beet analyses have been made at this Station, the results having been calculated from the original data and arranged by counties. The number of years during which beets have been received from the different counties is given in each case, and also the total number of samples received, and the average results of the examination of the beets for each county. In calculating the latter results the arithmetical mean of the averages for the different counties for each year has been figured out, and each season's results, therefore, considered a unit. The number of analyses made of beets from the same counties in the different seasons varied greatly, and it was therefore considered preferable to take the mean of the different seasons rather than of all separate analyses at hand for each particular county:

Compilation of results of sugar beet analyses in Wisconsin, 1890-99.

(Arranged by counties.)

County.	No. of years.	No. of samples.	Aver. size of topped beets.	Sugar in juice.	Puriety of juice.	Yield per acre.
			Lbs.	Per cent.	Per cent.	Tons.
Adams	3	11	1.4	13.92	78.6	9.7
Ashland	2	7	1.5	13.91	77.6	....
Barron	4	25	1.3	13.71	78.0	11.6
Bayfield	1	1	2.3	10.96	73.5	16.5
Brown	4	130	2.1	13.29	77.9	15.7
Buffalo	5	19	1.6	13.64	78.3	15.7
Burnett	3	6	1.4	15.14	77.6	12.5
Calumet	6	66	1.2	16.11	79.6	13.6
Chippewa	5	54	1.4	13.98	78.1	12.3
Clark	5	90	1.3	14.46	79.7	10.7
Columbia	6	55	2.0	12.92	74.7	13.4
Crawford	4	18	2.4	12.31	77.3	12.0
Dane	5	78	2.0	13.56	74.8	16.0
Dodge	5	70	1.9	13.16	76.2	16.5
Door	4	25	1.7	15.20	79.4	12.9
Douglas	3	12	1.0	15.56	83.5	16.1
Dunn	6	50	1.6	13.41	78.5	14.3
Eau Claire	3	73	1.7	11.42	75.2	12.5
Fond du Lac	5	49	2.0	12.08	73.9	13.1
Forest	3	4	1.7	11.21	72.4	10.5
Grant	4	35	2.4	10.55	70.7	13.1
Green	4	12	1.8	11.80	73.5	18.1
Green Lake	4	16	2.1	13.38	78.4	13.8
Iowa	4	12	1.7	12.91	75.4	19.9
Iron	1	1	2.2	9.96	64.7	15.5
Jackson	4	79	1.8	13.21	77.9	8.3
Jefferson	6	61	1.7	13.83	77.5	18.4
Juneau	4	18	2.3	13.69	78.1	15.8
Kenosha	5	31	1.8	13.95	77.3	21.2
Kewaunee	6	125	2.2	14.26	77.5	12.0
La Crosse	5	80	2.1	12.40	76.6	13.9
La Fayette	4	15	1.8	13.25	74.1	14.9
Langlade	2	16	1.8	12.21	76.1	17.6
Lincoln	5	18	1.0	16.32	82.7	9.6
Manitowoc	6	77	1.8	13.95	78.9	13.8
Marathon	4	62	1.4	13.49	76.3	13.5
Marinette	4	37	2.2	12.83	75.1	17.6
Marquette	4	34	1.2	14.56	80.4	14.1
Milwaukee	5	25	1.8	14.97	79.6	17.6
Monroe	5	46	1.6	13.37	76.1	11.4
Oconto	5	33	1.5	15.16	81.5	11.6
Oneida	3	8	1.4	15.23	77.3	10.6
Outagamie	5	108	2.1	13.19	77.0	19.7
Ozaukee	6	30	1.9	13.61	79.4	14.4
Pepin	5	14	2.2	16.33	81.0	16.1
Pierce	2	14	1.6	14.26	73.4	15.0
Polk	4	11	1.5	12.56	76.5	13.7
Portage	4	43	1.8	13.28	77.3	10.4
Price	3	13	1.3	13.67	74.8	8.6
Racine	5	27	2.1	14.85	79.7	18.3
Richland	4	26	1.8	12.04	71.8	14.1
Rock	5	72	1.6	14.23	78.1	14.1
St. Croix	5	54	1.4	13.69	76.9	12.1
Sauk	5	47	1.7	13.62	76.8	13.5
Sawyer	1	1	2.9	10.69	73.8	26.1
Shawano	5	37	1.5	14.40	79.5	13.5
Sheboygan	6	89	1.8	13.64	78.0	15.6
Taylor	5	27	1.3	15.57	78.5	10.8
Trempealeau	4	61	1.5	13.12	77.0	12.0
Vernon	2	27	2.3	12.55	74.5	13.1
Vilas	3	4	1.7	16.14	81.4	....
Walworth	5	23	1.6	14.73	79.7	15.5
Washburn	3	7	1.3	12.80	77.4	13.3
Washington	6	53	1.8	15.14	80.4	15.9
Waukesha	5	76	1.8	14.68	80.0	19.1
Waupaca	5	83	2.0	13.15	76.7	12.1
Waushara	4	35	1.6	14.34	79.4	18.0
Winnebago	6	52	2.0	13.89	78.5	14.1
Wood	5	30	1.6	14.27	79.1	11.6
Unidentified	3	15	1.5	13.44	74.7	....
Total No. of samples	....	2,772				

By carefully studying the results presented in the preceding table, we notice that they corroborate in general those of the last three seasons, and clearly show that our state has a rich-beet region and a poor-beet region. Beets of an average content of more than 16 per cent. of sugar in the juice were furnished by the counties of Calumet, Lincoln, Pepin and Vilas; beets containing on the average more than 15 per cent. sugar in the juice were grown in Burnett, Door, Douglas, Oconto, Oneida, Taylor and Washington counties, while the following counties grew beets containing between 14 and 15 per cent. sugar in the juice: Clark, Kewaunee, Marquette, Milwaukee, Pierce, Racine, Rock, Shawano, Walworth, Waukesha and Wood. By reference to a state map it will be seen that all the counties mentioned above lie either in the eastern, the extreme northwest, or central northern sections of the state. On the other hand, the counties furnishing beets of less than 13 per cent. sugar in the juice are located in the southwestern and central-western part of the state. These counties are Columbia, Crawford, Eau Claire, Green, Iowa, La Crosse, Richland, and Vernon. All these counties are located in the portion of the state known by geologists as the *driftless area*, or in the sandstone region immediately north of this area. The counties which have furnished rich beets, on the other hand, are in the *glacial-drift area*, either in the limestone region (eastern Wisconsin) or the Keweenawan or copper-bearing group in the extreme northwestern counties of the state. A few counties outside of the driftless area gave low results, viz., Fond du Lac, Forest, Langlade, Marinette, Polk, Sawyer and Washburn, but it seems likely that the poor showing made by these counties is either accidental, or may be due to the small number of analyses received from farmers living there, and the averages do not, therefore, give a true expression of the quality of beets which can be produced there; with the small number of analyses available from most of these counties we are hardly in position to generalize as to their adaptability to sugar beet culture. The purity of the beets corresponds, in general, very closely to the sugar contents, high sugar contents being accompanied by a high purity, and *vice versa*.

The conclusion stated in the preceding are backed by the

* Bull. 64 of this Station.

results of six years' work during varying seasons and with beets grown by different farmers under greatly different conditions. Attention was first called to the characteristic differences between different sections of our state, as regards the quality of the beets grown in each, when the results for the season of 1897 were published*, and it was then suggested that the differences in the quality of the beets found were due to the character of the soil in the different sections, the rich-beet belt having, generally speaking, a soil rich in lime, and the poor-beet belt a soil low in line. The data presented in the preceding compilation of six years' sugar beet analyses prove the correctness of the position then taken, it would seem, beyond a reasonable doubt, and we may, therefore, be justified in accepting it as an established fact.

The map of Wisconsin shown on the opposite page has been prepared under the direction of the writer, and is based on the data given in the last table; the counties of the state have been marked in a different manner, according to the average quality of sugar beets grown there, viz.:

(1) Counties furnishing beets with average contents of sugar in the juice above 14 per cent. and average purity above 80 per cent. (*rich-beet region,* peculiarly well adapted to sugar beet culture from an agricultural point of view).

(2) Counties furnishing beets with average contents of sugar in the juice between 13 and 14 per cent., and average purity between 78 and 80 per cent. (*good-beet region,* that may be found well adapted to sugar beet culture when more analyses are secured or when beets are grown by interested farmers and properly cared for).

(3) Counties furnishing beets with average contents of sugar in the juice below 12 per cent. and average purity below 75 (*poor-beet region,* where there can be but little hope that beets of a satisfactory sugar content and purity can be grown in such quantities as to warrant the establishment of sugar factories there).

The proper interpretation of the results of beet analyses made under conditions like those that have prevailed in this investiga-

* Bull. 64 of this Station.

tion has been repeatedly stated by the writer in earlier reports on this subject, and it is only necessary to repeat here that the results presented necessarily do not do full justice to the soil or the farmers of the various counties, for the reason that the beets in perhaps a majority of cases were grown as an experiment by parties who had had no previous experience in the culture of the crop, and without an intimate knowledge of its requirements as regards soil, manure, cultivation, etc., which only comes by experience and continued study. The results given can not, therefore, be considered an absolute guide as to the average quality of beets grown in this state; for such, the reader is referred to the published analyses of beets grown at our Experiment Station farm, or by single farmers within the rich-beet belt, whose names are published in the earlier bulletins on this subject, and who, year after year, have furnished samples of beets showing average sugar contents of 16 or more per cent., and purities of 85 per cent. or above.

While the data presented can not serve as an absolute guide as to the quality of Wisconsin-grown beets, they may be safely used as guides in deciding the relative order of excellence of different sections as to the quality of the beets grown there, since conditions that would tend to make the results too low in one section would be apt to prevail to a similar extent in other sections as well. The map of Wisconsin herewith presented, showing the differences in the quality of beets furnished by different counties, may for this reason be taken as a trustworthy guide as to relative adaptability of the different sections of our state to the culture of sugar beets, and as such, is recommended to the attention of capitalists and associations interested in the establishment of beet sugar factories in our state.

B. SUGAR BEET EXPERIMENTS AT THE UNIVERSITY FARM, SEASON 1899.

The experimental field laid out for sugar beets was a long, narrow strip of land, 40 feet wide and 550 feet long. The soil is a medium clay loam. Rape was grown on the land in 1898, which was manured in the spring; the rape was pastured off by

hogs on the south part, and by sheep in the north part. The field was divided into five plats (A–E), as shown in the accompanying diagram; plats A and E received no fertilizer; plat B was manured with well-rotted farm yard manure at the rate of 20 tons per acre; plat C received a potash and phosphoric-acid fertilizer (*Armour's Phosphate and Potash*), and plat D, a phosphoric-acid fertilizer (*Armour's Star Phosphate*), both these fertilizers being applied at the rate of 200 lbs. per acre. The object of applying the farmyard manure was to ascertain whether the yield of beets obtained could be increased, and that of applying the phosphoric-acid and potash fertilizers to hasten, if possible, the maturity of the beets and increase their co-efficients of purity. The field was plowed and subsoiled 16 inches deep on May 6; it was then thoroughly disced, and the fertilizers distributed and harrowed in, the barnyard manure being disced in. The field was pulverized on May 17, after the intervening rains, and the beet seed was planted on May 18, in rows 15 inches apart, running north and south. Two rows were planted of each variety, except of Nos. I and XIII, of which six and four rows, respectively, were put in.

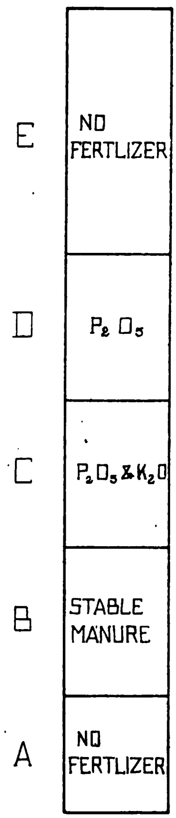

FIG. 37.

The seed planted was obtained partly from the U. S. Department of Agriculture, Section of Seed and Plant Introduction, and partly from private parties, viz., Nos. VII and VIII from the Oxnard Sugar Co., Grand Island, Neb.; No. IX from R. Weichsel & Co., Magdeburg, Germany, and Nos. X-XIII from Aug. Roelker & Sons, New York City.

The germination of the different kinds of seed was determined during the month of September in a Geneva seed tester by F. Cranefield, Assistant in Horticulture, with the results shown in the following table; the germination after five and twelve days is given in the table, and also the per cent. of germinative energy calculated on basis of the figures thus obtained.

Germination of beet seed, 189 9.

No.	Variety.	5 days.	12 days.	Germinative energy.
		Per cent.	Per cent.	Per cent.
I	Vilmorin's Improved	135	147	29
II	Zehringen	165	170	97
III	Dippe Kleinw	148	165	90
IV	Mangold	93	132	70
V	Biendorf Elite	101	126	80
VI	Kleinw. K. & S	123	145	85
VII	Vilmorin Neb	72	83	87
VIII	Kleinw. Neb	114	144	79
IX	Pitzschke	125	140	89
X	Rölker ZZ	156	177	88
XI	Rölker EE	135	147	92
XII	Rolker Dippe	116	141	82

As previously stated, the growing season was on the whole very favorable; the following table shows the monthly precipitation and temperature for Madison for April to October, 1899, obtained from the records of the Washburn Observatory. The

Meteorological data for Madison, Wis., season 1899.

	April.	May.	June.	July.	Aug.	Sept.	Oct.	Total or ave. April—Sept.
Precipitation, inches	2.69	4.92	2.64	3.22	3.57	3.35	1.58	20.39
Departure from normal	—.39	+1.06	—1.43	+.55	+1.30	+.52	+.17	+1.61
Av. temperature, ° C	48.5	58.2	63.8	71.8	72.1	59 8	53.5	63.2
Departure from normal	+1.7	+.6	—.1	—1.1	+1.8	—3.2	+3.5	—.1
No. rainy days	9	14	13	11	8	9	9	... .

dry weather that prevailed during a part of August and September possibly reduced the yields of beets to some extent, but as it was, the yield was considerably above the average. We aimed to leave a strong plant every nine inches in the row when the beets were thinned on June 20. The stand of beets on the different plats was practically perfect, there being, so far as could be seen, not an open space or a weed in the whole field.

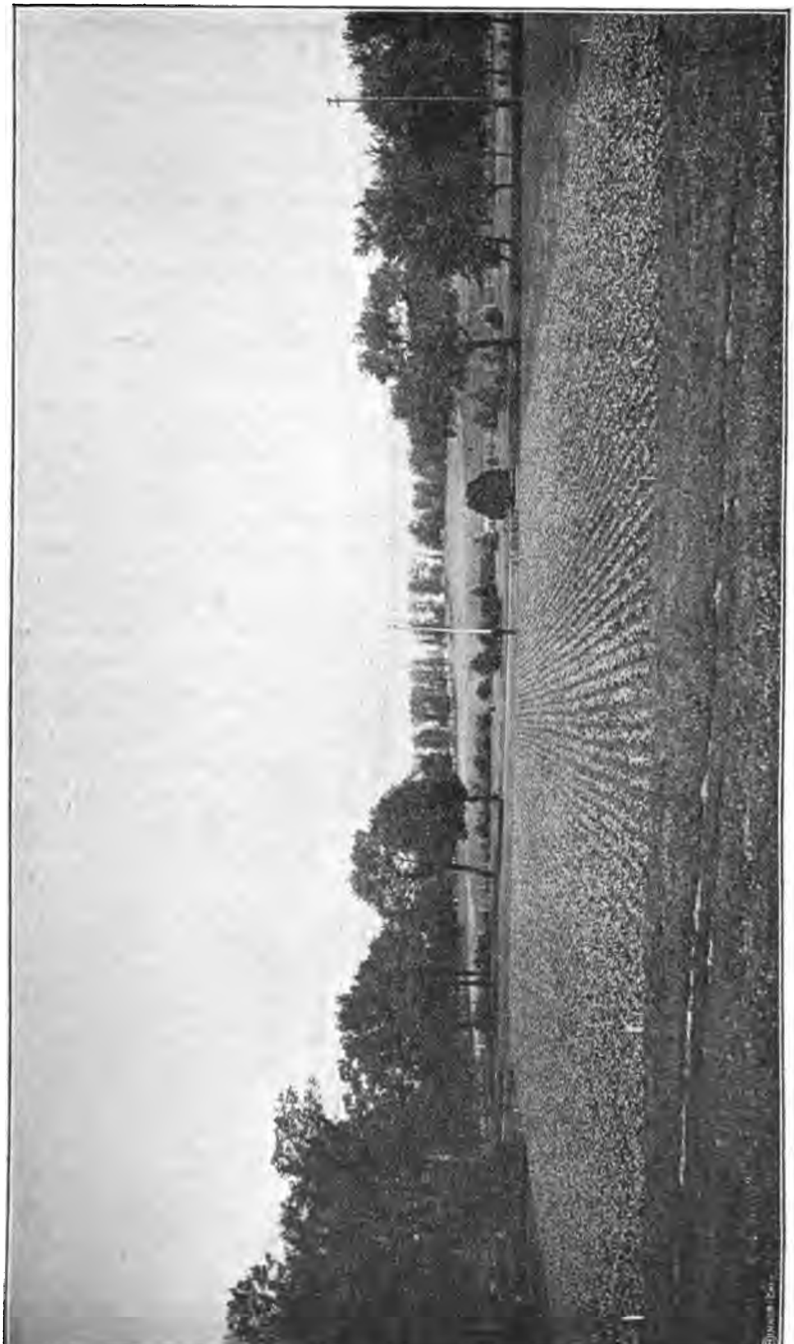

FIG. 83.—Sugar beet field at the University farm.

Samples of the beets grown on plat A were taken about every two weeks from August 24 till harvest time, October 11–14; the beets on the other plats were sampled September 2 and again at harvest, October 14.

The method of sampling was similar to that followed in previous years, all the beets in 8 ft.-length of an average inside row being dug in each case and weighed before and after topping; the per cent. of root was calculated from the weights thus obtained; two beets of average size were then selected for analysis, and the juice in the pulp expressed and polarized in a Schmidt-Haensch half-shadow polariscope.

The following table presents the average results of the analyses of the different varieties on each plat on the days given.

Results of analyses of sugar beets, University farm, 1899.

	Per ct. root.	Weight of topped beets.	Sugar in juice.	Purity.	Comparison with Average for Unfertilized Plats.		
					Weight	Sugar.	Purity.
Plat A.—No fertilizer.		Lbs.	Per ct.	Per ct.	Lbs.	Per ct	Per ct.
August 24	52	.52	14.17	82.5	....	....	....
September 7	73	.57	15.12	77.8	....	....	....
September 25	79	.76	14.80	79.8	....	....	....
October 14	....	.81	15.42	79.0	....	....	....
Plat B.—Barnyard manure.							
September 2	56	.62	13.96	80.8	+.05	−1.64	−1.9
October 14	....	.85	15.82	80.9	+.05	−.62	−2.5
Plat C.—Phosphoric acid and potash fertilizer.							
September 2	68	.50	17.48	88.9	−.07	+1.88	+6.2
October 14	....	.73	15 46	86.3	−.07	−.98	+2.9
Plat D.—Phosphoric acid fertilizer.							
September 2	63	.58	16.30	86.8	+.01	+.70	+4.1
October 14	....	.87	17.16	88.0	+.07	+.72	+4 6
Plat E.—No fertilizer.							
September 2	65	.57	16.08	87.6	....	....	....
October 14	....	.79	17.45	87.7	....	....	....

It will be observed that the beets continued to grow after the last day of sampling prior to harvest, and the greatest weight of topped beets, as well as the best analytical results were usually obtained in case of the samples taken at harvest time. There was a decrease in purity coefficient in case of plats A and C, and in case of the latter plat a deterioration in the quality of the beets grown from all the different kinds of seed but one took place between Sept. 2 and Oct. 14; the size of the beets increased uniformly, however, so that the maximum yield of sugar per acre was doubtless obtained by harvesting the beets at the latter date. The depressing influence of the barnyard manure on the quality of the beets is plainly seen from the figures given in the table, and also the improvement in the quality due to the special fertilization of phosphoric acid and potash, and of phosphoric acid alone.

In spite of the apparently uniform character of the field on which the beets were grown, considerable difference occurred in the quality of the beets on plats A and E, neither of which plats received any kind of fertilizer in the spring; the quality of the beets grown on plat A may have been somewhat lowered from the effect of the pasturing off the rape from the southern part of the field during the preceding summer and fall by hogs, which left the soil rather rich in organic matter for best results with sugar beets as regards their quality; the field rises gently in the extreme northern part (see Fig. 39), and the soil is somewhat lighter, which may also have contributed to the higher sugar content and purity of the beets on plat E.

In the preceding table the average analyses for plats B, C and D have been compared with the averages for plats A and E; it is believed that the results thus obtained indicate the true effect of the different systems of fertilization on the quality of the beets as sampled.

A comparison of the results of the analyses of beets grown from different kinds of seed shows that the Vilmorin and Kleinwanzleben seed furnished by the Oxnard Sugar Co. and the Rōlker Dippe Elite seed produced beets of early maturity and exceptional richness. The purity coefficient of the latter at harvest in case of plat E reached the remarkably high figure of

92.9 per cent., the sugar contained in the juice being 19.00 per cent., and the weight of topped beets .75 lb.

FIG. 39.—View of sugar beet field from the south.

The data obtained by Wisconsin farmers co-operating in the sugar beet work of the Station during the last season furnish some evidence as to the quality of the beets grown from the different kinds of seed. The results of the examination of the beets sent for analysis have been compiled according to the kind of seed from which the beets were grown; the data thus obtained are shown in the following table:

Compilation of analyses of beets grown from different kinds of seed.

Seed No.	Variety of seed.	No. of samples.	Weight of topped beets.	Sugar in juice.	Purity of juice.
			Lbs.	Per ct.	Per ct.
I	Vilmorin	39	1.3	15.01	79.8
II	Zehringen	12	1.3	13.90	79.9
III	Dippe Kleinwanzleben	72	1.4	14.44	82.1
IV	Mangold	21	1.3	16.24	82.7
V	Biendorf Elite	4	1.7	13.75	81.1
VI	Kleinwanzleben K & S	2	1.5	16.74	86.1

The results are not as high as those obtained at this Station, which could hardly be expected; the different kinds of seed gave, however, beets of a satisfactory sugar content and purity.

The preceding discussion refers to one side of the question only, viz., the quality of the beets grown; the other side, the total yields obtained, will now be considered. The data obtained at harvest time are shown in the following tables in detail for the different plats and kinds of beets, and also the total yields for each variety for the whole field.

Sugar beets grown at University farm, 1899.

No.	VARIETY.	PLAT A.		PLAT E.		PLAT B.		PLAT C.	
		Yield of beets per acre.	Per cent. of sugar.	Yield of beets per acre.	Per cent. of sugar.	Yield of beets per acre.	Per cent. of sugar.	Yield of beets per acre.	Per cent. of sugar.
		Lbs.		Lbs.		Lbs.		Lbs.	
I	Vilmorin.......	47,330	14.9	37,530	16.8	44,280	14.3	34,230	13.4
II	Zehringen......	40,530	13.4	29,050	16.2	39.020	16.5	30,130	14.5
III	Dippe Kl.......	40,230	15.4	29,800	17.0	39,070	16.3	28,670	15.8
IV	Mangold	37,600	13.0	28,870	16.6	38,940	16.9	32,100	13.0
V	Kleinw. Braune	36,490	13.3	28,780	17.4	41,930	14.0	30,890	14.6
VI	Kleinw. K. & S.	38,550	13.5	29,610	15.3	48,630	13.7	32,910	15.6
VII	Vilmorin Neb.	38,750	14.9	30,590	16.3	41,680	15.7	32,590	15.7
VIII	Kleinw. Neb...	38,470	16.2	29,980	16.6	44,620	14.6	35,940	15.1
IX	Pitzschke	38,080	10.6	29,150	16.2	47,110	15.5	38,940	14.7
X	Rölker Z Z.....	39,600	15.7	28,080	17.4	48,950	13.8	39,310	14.6
XI	Rölker E E.....	39,730	13.0	28,790	16.1	48,180	15.3	39,750	15.2
XII	Rölker Dippe..	41,690	14.6	30,210	18.1	49,030	15.2	39,430	14.9
XIII	Vilmorin.......	51,560	15.2	33,060	14.9	57,580	13.7	43,750	13.9
	Averages....	40,662	14.68	30,269	16.58	45,309	14.95	35,280	14.63

Sugar beets grown at University farm, 1899—continued.

No.	Variety.	Plat D.		Total for whole field and for all varieties.				
		Yield of beets per acre.	Per cent. of sugar.	Yield of beets.		Sugar.		
				From plat.	Per acre.	From plat.	Per acre.	Per cent.
		Lbs.		Lbs.		Lbs.	Lbs.	
I	Vilmorin........	37,700	15.0	3,744.3	39,300	565.9	5,937	15.11
II	Zehringen	38,660	16.2	1,099.3	34,830	170.8	5,411	13.53
III	Dippe Kleinw...	32,970	16.1	1,064.7	35,740	172.7	5,470	16.21
IV	Mangold........	36,410	15.4	1,082.4	34,300	164.8	5,220	15.23
V	Kleinw. Braune.	34,100	16.6	1,073.6	34.020	165.6	5,247	15.43
VI	Kleinw. K. & S..	35,180	15.4	1,147.1	36,340	169.0	5,355	14.73
VII	Vilmorin Neb...	38,660	16.7	1,136.6	36,000	181.3	5,744	15.95
VIII	Kleinw. Neb....	34,360	18.0	1,140.6	36,130	183.1	5,801	16.05
IX	Pitzschke.......	35,340	16 5	1,167.2	36,980	187.4	5,936	16.05
X	Rölker ZZ.......	38,870	16.5	1,195.6	37,870	187.6	5,930	15.69
XI	Rölker EE.......	36,070	17.3	1,185.7	37,580	185.2	6,005	15.62
XII	Rölker Dippe...	40,310	17.0	1,236.1	39,150	199.4	6,319	16.14
XIII	Vilmorin.......	41,330	15.3	2,747.5	43,530	398.8	6,319	14.52
	Aver. and totals	36,920	16.29	19,020.7	37,660	2,931.6	5,805	15.41

The average contents of sugar in the beet for all varieties for the different plats were as follows: Plat A, 14.68 per cent.; plat B, 14.95 per cent.; plat C, 14.63 per cent.; plat D, 16.29 per cent., and plat E, 16.58 per cent.; the average calculated yields of sugar per acre were 5,965, 6,771, 5,162, 6,013 and 5,017 lbs. for plat A–E, respectively. We notice, therefore, that the yield of beets from the plat that received farmyard manure was so much higher than the yields on the other plats that in spite of the fact that these beets were considerably lower in sugar content than the beets from at least two of the other plats, the yield of sugar was increased at the rate of over 1,200 lbs. per acre above the average yields for the plats not fertilized, and the yield of beets was increased at the rate of five tons per acre, as is shown in the following table of comparative results:

Comparison of yields of beets and sugar from different plats.

	Calculated Yields Per Acre.			Comparison With Average for Unfertilized Plats.		
	Beets.	Sugar.	Per cent. sugar.	Beets.	Sugar.	Per cent. sugar.
	Lbs.	Lbs.		Lbs.	Lbs.	
Plat A............	40,662	5,965	14.68	....	....	....
Plat B	45,309	6,771	14.95	+9,833	+1,280	−.68
Plat C............	35,280	5,162	14.63	−186	−329	−1.00
Plat D	36,920	6,013	16.29	+1,454	−522	+.66
Plat E	30,269	5,017	16.58	....	....	....
Average for field.	37,660	5,805	15.41	+2,194	+414	−.22

The average yield of beets for the whole field was at the rate of 18.8 tons, and that of sugar 5,805 lbs., the average content of sugar in the beets being 15.41 per cent. This, as will be observed, is a very good showing indeed, and is attributable to at least four causes: the favorable season, the high quality of seed, the perfect stand of beets obtained, and the close planting. The yield of beets from plat B (farmyard manure) over and above the average yield from the unfertilized plats, 9,833 lbs., would be worth about $22.00 at ordinary prices of sugar beets of this quality ($4.50 per ton); the value of the farmyard manure put on the plat will vary widely according to local conditions, and it is impossible to fix a value on it that will apply to all cases. An average price for well-rotted manure may be $1.50, and the cost per acre at the rate it was applied would therefore be $30.00. According to our best knowledge on the subject the effect of stable manure put on medium soils is continued for at least four years, and only 40 per cent. of its fertilizing value is taken out the first year; the cost of the fertilizer in this case would then be $12.00, and there was therefore realized a net gain of something like $10.00 per acre by the application of stable manure on the beet plat. The use of stable manure for beets is not generally recommended, and fresh manure should never be applied, as it greatly depresses the sugar content and purity of the beets; the well-rotted manure used in this experiment had a similar effect, but as has been shown, the yield of beets was increased so as to still make the application a financial success, and the quality of the beets on this plat was considerably above factory standard.

An increase in the yield of beets was also secured in case of plat D, fertilized with Star Phosphate fertilizer, which was applied at the rate of 200 lbs. per acre. The cost of this fertilizer is $18.00 per ton, and 200 lbs. were therefore worth $1.80. Since about 20 per cent. of dissolved bone and similar phosphates remain in the soil unexhausted after the first year when applied on medium soils, we charge $1.80 — .36 = $1.44 for the fertilizer in this case; as the increase in yield of beets was worth $3.64 (at $5.00 per ton), there was a net gain of $2.20 per acre of beets in case of this plat.

Plat C, fertilized with a phosphoric-acid and potash fertilizer, showed a small decrease in yield of beets and a marked decrease in the sugar content of the beets as compared with the data for the plots A and E. In view of the fact that the beets on this plat were higher in sugar than those of plat D (phosphoric-acid fertilizer only) at the first sampling of the beets, it is difficult to see that the poorer results obtained at harvest time from this lot can be due to the difference in the fertilizer applied; the cause of the deterioration in quality of the beets on this plat for this lot can hardly be sought in the addition of potash to the fertilizer; at any rate more than a single year's experiment would be required to establish such an effect.

The yield of beets obtained from the different kinds of beet seed will be seen from the last five columns of the preceding table; the data obtained do not give perfectly satisfactory information as to the comparative value of the seed, on account of the difference in the character of the field as we go eastward (No. I to XIII). It is evident, however, that the seed No. I and XIII (Vilmorin Improved, France) produced the largest yield of beets and of sugar with seed No. XII (Rölker Dippe Kleinw. Elite) a close second. There seems to be little difference between Nos. VI–IX, inclusive, while seed No. II, IV, V, III, gave the lowest results, in the order given, as regards yields of beets; considering the yields of total sugar lowest results were obtained in the following order, Nos. III, II, IV, V.

The sugar beet investigations of this Station are being continued during the present season, but no results of this year's work can be given in time for this report.

ANALYSES OF LICENSED COMMERCIAL FERTILIZERS, 1899.

F. W. WOLL AND ALFRED VIVIAN.

The following manufacturers have taken out a license for the sale of the brands of fertilizers given, in this State during the current year, in accordance with Wisconsin Statutes of 1898, sec. 1494c.

Station No.	Name of Manufacturer.	Name of Brand.
34	Darling & Co., Chicago, Ill	Darling's Tobacco Special.
35	Darling & Co., Chicago, Ill	Darling's Vegetable and Lawn Fertilizer.
36	Darling & Co., Chicago, Ill	Darling's Chicago Brand.
37	Currie Bros., Milwaukee, Wis	Currie's Complete Fertilizer for Lawns, Hay and Pasture.
38	Milwaukee Tallow and Grease Co., Milwaukee, Wis	Milwaukee Tallow and Grease Co.'s Bone Meal.
39	Armour Fertilizer Works, Chicago, Ill	Bone Meal.
40	Armour Fertilizer Works, Chicago, Ill	Ammoniated Bone and Potash.

The Station analyses of the brands given are shown in the following table. According to Wisconsin Statutes of 1898, section 1494c, each manufacturer "shall affix to every package of fertilizer sold . . . a statement of the following fertilizing constituents, namely: The percentage of nitrogen in an available form, of potash soluble in water, and of available phosphoric acid, soluble and reverted, as well as total phosphoric acid." The guaranteed composition of the licensed fertilizers is given in the table in connection with the results of our analyses of the samples furnished by the manufacturers in compliance with the state fertilizer law.

Analysis of licensed commercial fertilizers in Wisconsin, 1900.

Station No.	Name of Brand.	Moisture.	Nitrogen.		Phosphoric Acid.							Potash.	
			Found.	Guaranteed.	Soluble. Found.	Soluble. Guaranteed.	Reverted.	Available. Found.	Available. Guaranteed.	Total. Found.	Total. Guaranteed.	Found.	Guaranteed.
		Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct	Pr. ct.
34	Darling's Tobacco Special	5.00	3.36	3.3	4.68	....	2.64	7.32	7.0	11.31	8.0	7.89	7.0
35	Darling's Vegetable and Lawn Fertilizer	9.30	3.48	3.3	4.09	....	2.89	6.98	7.0	11.50	8.0	8.93	7.0
36	Darling's Chicago Brand	4.50	2.23	2.0	5.65	....	3.34	8.99	7.0	12.82	11.0	1.54	1.0
37	Currie's Complete Fertilizer for Lawns, Hay and Pasture	2.00	5.18	5.1	.50	....	2.78	3.28	....	12.70	12.7	7.88	7.8
38	Milwaukee Tallow and Grease Co.'s Bone Meal	5.00	4.20	4.0	....	....	....	....	....	22.26	20.0	....	....
39	Bone Meal	4.90	4.10	2.5	....	....	....	....	....	24.58	24.0	....	....
40	Ammoniated Bone and Potash	7.84	2.10	2.4	4.76	....	2.79	7.55	6.0	10.00	8.0	2.50	2.0

The mechanical analysis of the samples of bone meal included among the licensed brands of fertilizers gave the following results, the portion passing through a sieve of 1-50 inch mesh being designated as *fine-ground,* and that remaining on such a sieve as *coarse.*

Mechanical analysis of bone meal.

Station No.	Brand.	Fine-ground	Coarse.
		Per ct.	Per ct.
38	Milwaukee Tallow and Grease Co.'s Bone Meal	89	11
39	Bone Meal	59	41

Fertilizer inspection.—It is impossible to tell from the appearance or odor of a commercial fertilizer whether it contains a large amount of valuable fertilizing ingredients or only a very small amount. There is therefore a strong temptation for irresponsible parties to make and sell inferior or even valueless goods as standard fertilizing materials; so much so, that it has been found necessary in all states where the fertilizer business has grown to be of any importance, that the State should in some way supervise their sale. Laws regulating the sale of commercial fertilizers are at the present time in force in a large majority of the states in the Union. The Wisconsin fertilizer law which was passed by the legislature in 1895 is given in full in the following pages. According to the provisions of the law, all commercial fertilizers sold in this state at a cost exceeding $10.00 per ton are to be licensed. They must be sold on a guarantee of certain amounts of valuable fertilizing ingredients contained therein, and the director of the experiment station, on whom is laid the duty of seeing to it that the law is enforced, is authorized, in person or by deputy, to take samples of all commercial fertilizers sold in this state which come within the scope of the law. In case of licensed fertilizers it may thus be ascertained whether these come up to the guaranteed composition, and when it is found that parties are selling fertilizers without complying with the provisions of law, the offenders may be brought before

the proper legal authorities and convicted according to section 1494*d* of Wisconsin Statutes of 1898. This section imposes a fine of $100.00 for the first offense and $200.00 for each subsequent offense.

It is hoped that all dealers in commercial fertilizers in the State will comply with the law in all particulars, and that they as well as purchasers of such fertilizers, will assist in the enforcement of the law by giving notice of violations of the same. A strict compliance with the law is for the best interests of all honest dealers and consumers alike. Only firms that live up to the requirements of the law and have taken out licenses for the sale of their brands of fertilizers should be patronized; the law does not offer purchasers any protection against dealers in other states who sell inferior or fraudulent goods.

TABLES FOR USE IN KJELDAHL METHOD FOR DETERMINATION OF NITROGEN.

ALFRED VIVIAN.

The following tables, which have been in use in this laboratory for some years, have been found convenient where large numbers of nitrogen determinations are being made; they are published here in the hope that they may prove useful to others working with the Kjeldahl method.

Table I gives the per cent of nitrogen (calculated on the basis of one gram of material) corresponding to a given titration. The figures in heavy type under the heading "c. c. of $\frac{N}{5}$ acid" represent the number of c. c. of $\frac{N}{5}$ acid placed in the receiver before distillation. The column headed "c. c. of $\frac{N}{10}$ alkali" gives the amount of $\frac{N}{10}$ alkali used for titrating back the excess of acid after distillation.

To use the table, the nitrogen in the reagents (as found in blank determinations) is calculated to its equivalent in c. c. of $\frac{N}{10}$ alkali; this figure is added to the number of c. c. used for titrating back, and the sum of these figures found in the column headed "c. c. of $\frac{N}{10}$ alkali." The per cent of nitrogen will then be given at the intersection of this horizontal line with the vertical column under the figure representing the number of c. c. of $\frac{N}{5}$ acid used.

Example.—1 gram of material was taken for nitrogen determination. 6 c. c. of $\frac{N}{5}$ acid was placed in the receiver. After distillation it required 0.95 c. c. of $\frac{N}{10}$ alkali to titrate back the excess of acid. Nitrogen in reagents = 0.10 c. c. of $\frac{N}{10}$ alkali. 0.95 c. c. + 0.10 c. c. = 1.05 c. c. Look for 1.05 in first column, follow the horizontal line to its intersection with column under heavy figure 6, and the per cent of nitrogen (4.05) is found.

(Continued on page 265.)

TABLE I.—*Per cent. of nitrogen corresponding to any titration where $\frac{N}{2}$ acid and $\frac{N}{10}$ alkali are used, calculated for one gram material.*

C. C. of $\frac{N}{10}$ alkali.	C. C. OF $\frac{N}{2}$ ACID.									
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
0.00	0.70	1.40	2.10	2.80	3.50	4.20	4.90	5.60	6.30	7.00
0.05	0.69	1.39	2.09	2.79	3.49	4.19	4.89	5.59	6.29	6.99
0.10	0.69	1.39	2.09	2.79	3.49	4.19	4.89	5.59	6.29	6.99
0.15	0 68	1.38	2.08	2.78	3.48	4.18	4.88	5.58	6.28	6.98
0.20	0.67	1.37	2.07	2.77	3.47	4.17	4 87	5.57	6.27	6.97
0.25	0.67	1.37	2.07	2.77	3.47	4.17	4.87	5 57	6.27	6.97
0.30	0.66	1.36	2.06	2.76	3.46	4.16	4.86	5.56	6.26	6.96
0.35	0.65	1.35	2.05	2.75	3.45	4.15	4.85	5.55	6.25	6 95
0.40	0.64	1.34	2.04	2.74	3.44	4.14	4.84	5.54	6.24	6.94
0.45	0.64	1.34	2.04	2.74	3.44	4.14	4.84	5.54	6.24	6.94
0.50	0.63	1.33	2.03	2.73	3.43	4.13	4.83	5.53	6.23	6.93
0.55	0.62	1.32	2.02	2.72	3.42	4.12	4.82	5.52	6.22	6.92
0.60	0.62	1.32	2.02	2.72	3.42	4.12	4.82	5.52	6.22	6.92
0.65	0.61	1.31	2.01	2 71	3.41	4.11	4.81	5.51	6.21	6.91
0.70	0.60	1.30	2.00	2.70	3.40	4.10	4.80	5.50	6.20	6.90
0.75	0.60	1.30	2.00	2 70	3.40	4.10	4.80	5.50	6.20	6.90
0.80	0.59	1.29	1.99	2.69	3.39	4.09	4.79	5.49	6.19	6.89
0.85	0.58	1.28	1.98	2.68	3.38	4.08	4.78	5.48	6.18	6.88
0.90	0.57	1.27	1 97	2.67	3.37	4.07	4.77	5.47	6.17	6 87
0.95	0.57	1.27	1.97	2.67	3.37	4.07	4.77	5.47	6.17	6.87
1.00	0.56	1.26	1 96	2.66	3 36	4 06	4.76	5.46	6.16	6.86
1.05	0.55	1.25	1 95	2.65	3.35	4.05	4.75	5.45	6.15	6.85
1.10	0.55	1.25	1.95	2 65	3.35	4.05	4.75	5.45	6 15	6.85
1.15	0.54	1.24	1.94	2.64	3.34	4.04	4.74	5.44	6.14	6.84
1.20	0.53	1.23	1.93	2.63	3.33	4.03	4.73	5.43	6.13	6.83
1.25	0.53	1.23	1.93	2.63	3.33	4.03	4.73	5.43	6.13	6.83
1.30	0.52	1.22	1.92	2.62	3.32	4.02	4.72	5.42	6.12	6.82
1.35	0 51	1.21	1.91	2.61	3.31	4.01	4.71	5.41	6.11	6.81
1.40	0.50	1.20	1.90	2.60	3.30	4.00	4.70	5.40	6.10	6.80
1.45	0.50	1.20	1.90	2.60	3.30	4.00	4.70	5.40	6.10	6.80
1.50	0.49	1.19	1.89	2.59	3.29	3.99	4.69	5.39	6.09	6.79
1.55	0.48	1 18	1.88	2.58	3.28	3.98	4.68	5.38	6.08	6.78
1.60	0.48	1.18	1.88	2.58	3.28	3.98	4.68	5.38	6.08	6.78
1.65	0.47	1.17	1.87	2.57	3 27	3.97	4.67	5.37	6.07	6.77
1.70	0.46	1.16	1.86	2.56	3.26	3.96	4.66	5.36	6.06	6.76
1.75	0.46	1.16	1.86	2.56	3.26	3.96	4.66	5.36	6.06	6.76
1.80	0.45	1.15	1.85	2.55	3.25	3.95	4.65	5.35	6 05	6.75
1.85	0 44	1.14	1.84	2.54	3.24	3.94	4.64	5.34	6.04	6.74
1.90	0.43	1.13	1.83	2.53	3.23	3.93	4.63	5.33	6.03	6.73
1.95	0.43	1.13	1.83	2.53	3.23	3.93	4.63	5.33	6.03	6.73
2.00	0 42	1.12	1.82	2.52	3.22	3.92	4.62	5.32	6.02	6.72
2.05	0.41	1.11	1.81	2.51	3.21	3.91	4.61	5.31	6.01	6.71
2.10	0.41	1.11	1.81	2.51	3.21	3.91	4.61	5.31	6 01	6.71
2.15	0.40	1.10	1.80	2.50	3.20	3.90	4.60	5.30	6.00	6.70
2.20	0.39	1.09	1.79	2.49	3.19	3.89	4.59	5.29	5.99	6.69
2.25	0.39	1.09	1.79	2.49	3.19	3.89	4.59	5.29	5.99	6.69
2.30	0.38	1.08	1.78	2.48	3.18	3.88	4.58	5.28	5.98	6.68
2.35	0.37	1.07	1.77	2.47	3.17	3.87	4.57	5.27	5.97	6.67
2.40	0.36	1.06	1.76	2.46	3.16	3.86	4.56	5.26	5.96	6 66
2.45	0.36	1.06	1.76	2.46	3.16	3.86	4.56	5.26	5.96	6.66

TABLE I.—Continued.

C. C. of $\frac{N}{10}$ alkali.	C. C. OF $\frac{N}{2}$ ACID.								
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
2.50	0.35	1.05	1.75	2.45	3.15	3.85	4.55	5.25	5.95	6.65
2.55	0.34	1.04	1.74	2.44	3.14	3.84	4.54	5.24	5.94	6.64
2.60	0.34	1.04	1.74	2.44	3.14	3.84	4.54	5.24	5.94	6.64
2.65	0.33	1.03	1.73	2.43	3.13	3.83	4.53	5.23	5.93	6.63
2.70	0.32	1.02	1.72	2.42	3.12	3.82	4.52	5.22	5.92	6.62
2.75	0.32	1.02	1.72	2.42	3.12	3.82	4.52	5.22	5.92	6.62
2.80	0.31	1.01	1.71	2.41	3.11	3.81	4.51	5.21	5.91	6.61
2.85	0.30	1.00	1.70	2.40	3.10	3.80	4.50	5.20	5.90	6.60
2.90	0.29	0.99	1.69	2.39	3.09	3.79	4.49	5.19	5.89	6.59
2.95	0.29	0.99	1.69	2.39	3.09	3.79	4.49	5.19	5.89	6.59
3.00	0.28	0.98	1.68	2.38	3.08	3.78	4.48	5.18	5.88	6.58
3.05	0.27	0.97	1.67	2.37	3.07	3.77	4.47	5.17	5.87	6.57
3.10	0.27	0.97	1.67	2.37	3.07	3.77	4.47	5.17	5.87	6.57
3.15	0.26	0.96	1.66	2.36	3.06	3.76	4.46	5.16	5.86	6.56
3.20	0.25	0.95	1.65	2.35	3.05	3.75	4.45	5.15	5.85	6.55
3.25	0.25	0.95	1.65	2.35	3.05	3.75	4.45	5.15	5.85	6.55
3.30	0.24	0.94	1.64	2.34	3.04	3.74	4.44	5.14	5.84	6.54
3.35	0.23	0.93	1.63	2.33	3.03	3.73	4.43	5.13	5.83	6.53
3.40	0.22	0.92	1.62	2.32	3.02	3.72	4.42	5.12	5.82	6.52
3.45	0.22	0.92	1.62	2.32	3.02	3.72	4.42	5.12	5.82	6.52
3.50	0.21	0.91	1.61	2.31	3.01	3.71	4.41	5.11	5.81	6.51
3.55	0.20	0.90	1.60	2.30	3.00	3.70	4.40	5.10	5.80	6.50
3.60	0.20	0.90	1.60	2.30	3.00	3.70	4.40	5.10	5.80	6.50
3.65	0.19	0.89	1.59	2.29	2.99	3.69	4.39	5.09	5.79	6.49
3.70	0.18	0.88	1.58	2.28	2.98	3.68	4.38	5.08	5.78	6.48
3.75	0.18	0.88	1.58	2.28	2.98	3.68	4.38	5.08	5.78	6.48
3.80	0.17	0.87	1.57	2.27	2.97	3.67	4.37	5.07	5.77	6.47
3.85	0.16	0.86	1.56	2.26	2.96	3.66	4.36	5.06	5.76	6.46
3.90	0.15	0.85	1.55	2.25	2.95	3.65	4.35	5.05	5.75	6.45
3.95	0.15	0.85	1.55	2.25	2.95	3.65	4.35	5.05	5.75	6.45
4.00	0.14	0.84	1.54	2.24	2.94	3.64	4.34	5.04	5.74	6.44
4.05	0.13	0.83	1.53	2.23	2.93	3.63	4.33	5.03	5.73	6.43
4.10	0.13	0.83	1.53	2.23	2.93	3.63	4.33	5.03	5.73	6.43
4.15	0.12	0.82	1.52	2.22	2.92	3.62	4.32	5.02	5.72	6.42
4.20	0.11	0.81	1.51	2.21	2.91	3.61	4.31	5.01	5.71	6.41
4.25	0.11	0.81	1.51	2.21	2.91	3.61	4.31	5.01	5.71	6.41
4.30	0.10	0.80	1.50	2.20	2.90	3.60	4.30	5.00	5.70	6.40
4.35	0.09	0.79	1.49	2.19	2.89	3.59	4.29	4.99	5.69	6.39
4.40	0.08	0.78	1.48	2.18	2.88	3.58	4.28	4.98	5.68	6.38
4.45	0.08	0.78	1.48	2.18	2.88	3.58	4.28	4.98	5.68	6.38
4.50	0.07	0.77	1.47	2.17	2.87	3.57	4.27	4.97	5.67	6.37
4.55	0.06	0.76	1.46	2.16	2.86	3.56	4.26	4.96	5.66	6.36
4.60	0.06	0.76	1.46	2.16	2.86	3.56	4.26	4.96	5.66	6.36
4.65	0.05	0.75	1.45	2.15	2.85	3.55	4.25	4.95	5.65	6.35
4.70	0.04	0.74	1.44	2.14	2.84	3.54	4.24	4.94	5.64	6.34
4.75	0.04	0.74	1.44	2.14	2.84	3.54	4.24	4.94	5.64	6.34
4.80	0.03	0.73	1.43	2.13	2.83	3.53	4.23	4.93	5.63	6.33
4.85	0.02	0.72	1.42	2.12	2.82	3.52	4.22	4.92	5.62	6.32
4.90	0.01	0.71	1.41	2.11	2.81	3.51	4.21	4.91	5.61	6.31
4.95	0.01	0.71	1.41	2.11	2.81	3.51	4.21	4.91	5.61	6.31

TABLE II.— *Conversion of nitrogen into ammonia and protein* (= *N x 6.25*).

N.	NH_3.	Protein (N x 6.25.)	N.	NH_3.	Protein (N x 6.25).	N.	NH_3.	Protein (N x 6.25).
0.1	0.12	0.63	4.0	4.86	25.00	8.0	9.71	50.00
.2	.24	1.25	.1	4.98	25.63	.1	9.83	50.63
.3	.36	1.88	.2	5.10	26.25	.2	9.95	51.25
.4	.49	2.50	.3	5.22	26.88	.3	10.08	51.88
.5	.61	3.13	.4	5.34	27.50	.4	10.20	52.50
.6	.73	3.75	.5	5.46	28.13	.5	10.32	53.13
.7	.85	4.38	.6	5.58	28.75	.6	10.44	53.75
.8	.97	5.00	.7	5.71	29.38	.7	10.56	54.38
.9	1.09	5.63	.8	5.83	30.00	.8	10.68	55.00
1.0	1.21	6.25	.9	5.95	30.63	.9	10.80	55.63
.1	1.34	6.88	5.0	6.07	31.25	9.0	10.93	56.25
.2	1.46	7.50	.1	6.19	31.88	.1	11.05	56.88
.3	1.58	8.13	.2	6.31	32.50	.2	11.17	57.50
.4	1.70	8.75	.3	6.43	33.13	.3	11.29	58.13
.5	1.82	9.38	.4	6.56	33.75	.4	11.41	58.75
.6	1.94	10.00	.5	6.68	34.38	.5	11.53	59.38
.7	2.06	10.63	.6	6.80	35.00	.6	11.65	60.00
.8	2.19	11.25	.7	6.92	35.63	.7	11.78	60.63
.9	2.31	11.88	.8	7.04	36.25	.8	11.90	61.25
2.0	2.43	12.50	.9	7.16	36.88	.9	12.02	61.88
.1	2.55	13.13	6.0	7.28	37.50	10.0	12.14	62.50
.2	2.67	13.75	.1	7.41	38.13	.1	12.26	63.13
.3	2.79	14.38	.2	7.53	38.75	.2	12.38	63.75
.4	2.91	15.00	.3	7.65	39.38	.3	12.50	64.38
.5	3.04	15.63	.4	7.77	40.00	.4	12.63	65.00
.6	3.16	16.25	.5	7.89	40.63	.5	12.75	65.63
.7	3.28	16.88	.6	8.01	41.25	.6	12.87	66.25
.8	3.40	17.50	.7	8.13	41.88	.7	12.99	66.88
.9	3.52	18.13	.8	8.26	42.50	.8	13.11	67.50
3.0	3.64	18.75	.9	8.38	43.13	.9	13.23	68.13
.1	3.76	19.38	7.0	8.50	43.75	11.0	13.35	68.75
.2	3.88	20.00	.1	8.62	44.38	.1	13.48	69.38
.3	4.01	20.63	.2	8.74	45.00	.2	13.60	70.00
.4	4.13	21.25	.3	8.86	45.63	.3	13.72	70.63
.5	4.25	21.88	.4	8.98	46.25	.4	13.84	71.25
.6	4.37	22.50	.5	9.11	46.88	.5	13.96	71.88
.7	4.49	23.13	.6	9.23	47.50	.6	14.08	72.50
.8	4.61	23.75	.7	9.35	48.13	.7	14.20	73.13
.9	4.73	24.38	.8	9.47	48.75	.8	14.33	73.75
			.9	9.59	49.38	.9	14.45	74.38
						12.0	14.57	75.00

N.	.01	.02	03	.04	.05	.06	.07	.08	.09
NH_3..	.01	.02	.04	.05	.06	.07	.09	.10	.11
Protein.	.06	.13	.19	.25	.31	.38	.44	.50	.56

(Continued from page 261.)

In case the amount of $\frac{N}{10}$ alkali required is 5 c. c. or over, the number of c. c. used is divided by 5, and the remainder taken for the c. c. of $\frac{N}{10}$ alkali, the quotient being subtracted from the number of c. c of $\frac{N}{2}$ acid used, before the table is applied.

Example.— 10 c. c. $\frac{N}{2}$ acid were used and 17.25 c. c. $\frac{N}{10}$ alkali required to titrate back. $17.25 \div 5 = 3$, with a remainder of 2.25. $10 - 3 = 7$. The figure in the table under 2.25 c. c. $\frac{N}{10}$ alkali and 7 c. c. $\frac{N}{2}$ acid (4.59) is the correct per cent of N.

The table may be used for any quantity of acid above 10 c. c. by finding the per cent of N in the table under the unit figure, and adding seven per cent for each ten, in the number of c. c. used.

Example.— 18 c. c. of acid was required. 1.25 c. c. alkali used to titrate back. 8 c. c. acid and 1.25 c. c. alkali gives 5.42 per cent N. $5.42 + 7.0 =$ 12.42 per cent N = per cent N for 18 c. c. acid and 1.25 c. c. alkali.

As the *weight* of nitrogen corresponding to a given titration may be found from the table by moving the decimal point two places to the left, the calculation of the per cent of nitrogen is reduced to a single division whatever weight of material is used.

Example.— 1.3286 grams of material was taken for analysis, 7 c. c. $\frac{N}{2}$ acid was used and 4.50 c. c. $\frac{N}{10}$ alkali required to titrate back. By moving decimal point two places to left in the number found in table under 7 c. c. acid and 4.50 c. c. alkali .0427 (equals weight of N in 1.3286 grams material) is obtained.

$$.0427 \div 1.3286 \times 100 = 3.21 = \text{per cent of N.}$$

INVESTIGATION OF FLOWER BUDS.

E. S. GOFF.

In the report of this Station for 1899 (pp. 289–303) is recorded an investigation made by the writer during the summer and autumn of that year upon "The Origin and Early Development of Flowers in the Cherry, Plum, Apple and Pear." The date of the first appearance of the flowers on one tree of each of the fruits mentioned is there stated, and the progress of the flowers is traced to the end of October of that year.

This investigation has been continued through the past season. It was the aim, 1st, to continue the study of the development of the flowers of the above-named fruits through the winter and the following spring to ascertain something of the temperature at which the development was resumed in spring; 2nd, to repeat the observations upon the same fruits during the season of 1900 to learn how far the times of appearance of the flowers might vary during the two seasons; and 3rd, to extend the investigation to the peach and the strawberry.

The manner of conducting these investigations was described in detail in our report for 1899. In brief, the buds were imbedded, chiefly in paraffin, and cut into sections with the microtome; the sections were then stained and examined under the microscope. The past season the same methods were employed in the main, but at the beginning of autumn a method was found by which it was possible to determine, in most cases, the condition of the buds, as to flower development without imbedding. This method proved of great value as it enabled the observations to be extended to a large number of trees of various varieties which would otherwise have been impracticable.

THE RESUMPTION OF FLOWER GROWTH IN SPRING.

The temperatures at which flower development in our fruit plants becomes active in spring is of interest in connection with the study of hardiness. While the data at hand do not permit definite conclusions, they throw some light upon this question. The observations were continued during the past winter and until April 21st, 1900, at which time the swelling of the flower-buds was so manifest that it was thought unnecessary to continue them further.

No evidences of activity were apparent in the buds from the commencement of freezing weather in autumn until after the middle of March. The winter of 1899–1900, while not a severe one for this climate, had no strikingly warm periods. The following graphic diagram shows the maximum daily shade temperature from March 23, to April 21, as recorded at the Washburn observatory, near the Station orchard. An unsuccessful

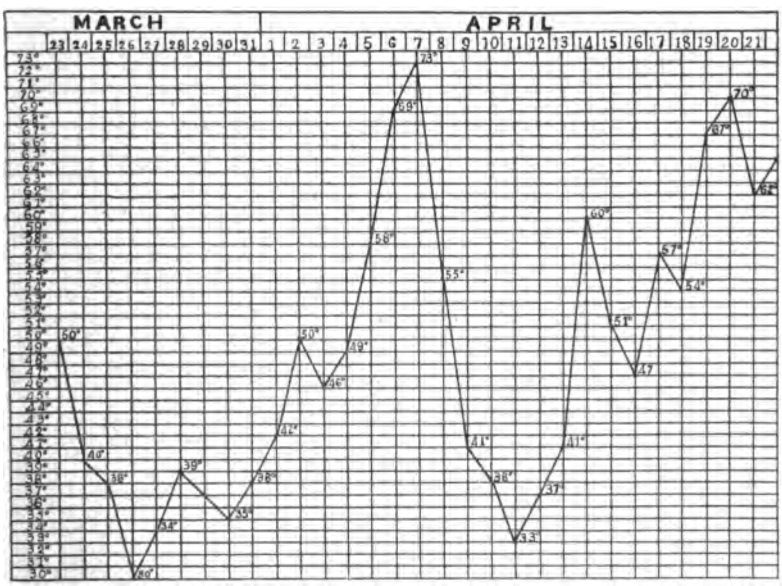

FIG. 40.—Showing maximum daily shade temperatures at Washburn Observatory from March 23 to April 21, 1900.

attempt was made to secure a thermograph record of the sunshine temperature also during this period. The actual temperature of the embryo flowers within the buds was, however, prob-

ably different from both the sunshine and the shade temperatures, for while the buds were exposed to the sun's rays, some evaporation was going on at their surface which must have lowered their temperature, and the flowers were separated from the sun's rays by several thicknesses of moist bud scales, with interposed layers of down. The maximum shade temperature perhaps corresponds more nearly to the maximum temperature of the inclosed flowers than would the maximum sunshine temperature.

Following the temperature diagram, are presented drawings intended to show the condition of the flowers from time to time. The dates at which the buds were taken are recorded beneath the drawings, and all are magnified about 40 times, except as otherwise stated.

Comparing the illustrations of the cherry flowers with the temperature diagram, it appears that the anthers did not begin to swell much until the temperature reached nearly 70° F. Examination with a higher power suggests that some change occurred as early as March 30. It is interesting to note that the sudden drop in temperature from 73° on April 7, to 33° on April 11, did not check the swelling of the flowers at once, but that the effect of this cold period was noticeable the following week, though the temperature in the meantime had risen to 60° on the 14th. With the gradual rise in temperature from the 16th to the 20th, the swelling was much more marked than it had been previously. From these data it appears that the buds do not quickly respond to a change in maximum temperatures.

The ovules do not appear equally developed in these drawings because the section drawn did not always include the same part of the pistil. It would appear, however, that no marked change occurred in the development of the ovule until the anthers had begun to swell.

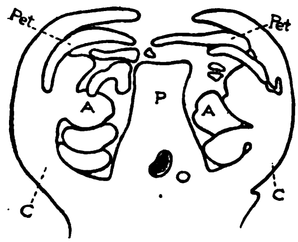

FIG. 41.—Section of cherry flower from bud taken Oct. 30, 1899. A, anthers; P, pistil; O, ovule; Pet, petals; C, calyx.

FIG. 42.—From bud taken Jan. 1, 1900.

FIG. 43.—From bud taken Feb. 10.

FIG. 44.—From bud taken March 12.

FIG. 45.—From bud taken March 23.

FIG. 46.—From bud taken March 30.

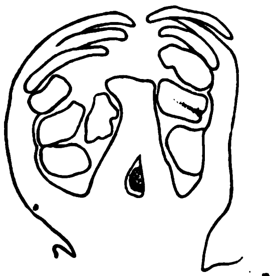

FIG. 47.—From bud taken April 6.

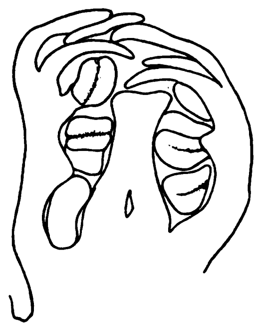

FIG. 48.—From bud taken April 7.

FIG. 49.—From bud taken April 11.

FIG. 50.—From bud taken April 17.

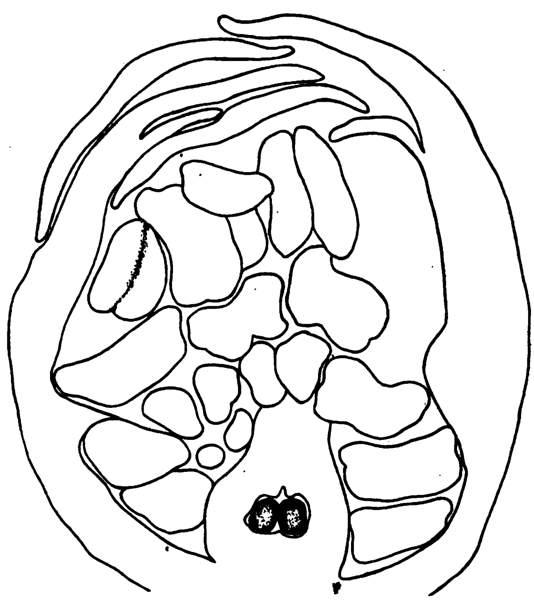

FIG. 21.—From bud taken April 21.

Referring the illustration of the plum anthers to the temperature table, it appears that some change had occurred as early as April 2. Fig. 52 shows the pollen mother-cells as they appeared in a bud taken March 23, and they appeared much like this at the beginning of winter. Fig. 53 shows them as they appeared April 2, from which it is clear that a change has taken place. The mother-cells are more sharply defined and have commenced to separate from one another. In Fig. 54, from a bud taken April 6, the anther has evidently commenced to swell, and the separation of the mother-cells is somewhat more marked. The swelling and separation are much more conspicuous in Fig. 55, from a bud taken April 14.

FIG 52.—Section of anther of plum from bud taken March 23, 1900, magnified about 225 times.

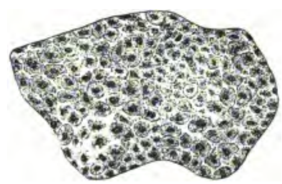

FIG. 53.—Section of anther of plum from bud taken April 2, 1900, magnified about 225 times.

FIG. 54.—Section of anther of plum from bud taken April 6, 1900, magnified about 225 times.

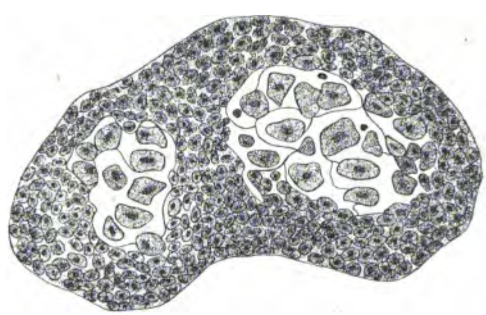

FIG. 55.—Section of plum anther from bud taken April 14, 1900, magnified about 225 times.

It appears, therefore, that in both the cherry and plum some differentiation of the pollen mother-cells may occur before the maximum shade temperature exceeds 50° F., but that no marked swelling of the anthers occurs until the temperature ap-

proaches 70°. From the illustrations of the apple flowers Fig. 56 and 57, it would appear that no perceptible swelling of the anthers occurred until after April 10. The section of a pear flower (Fig. 58), from a bud taken March 30, shows no advance over others taken Dec. 1, 1899.

FIG. 56. — Section of apple flower from bud taken March 30, 1900, magnified about 20 times.

FIG. 57. — Section of apple flower from bud taken April 10, 1900, magnified about 20 times.

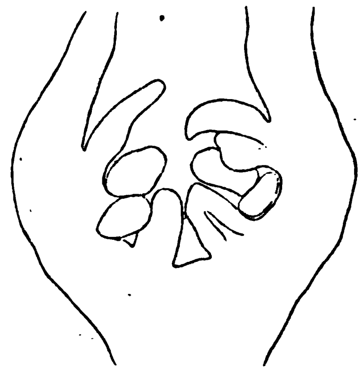

FIG. 58.—Section of pear flower from bud taken Mar. 30, 1900, magnified about 40 times.

A REPETITION OF THE OBSERVATIONS OF 1899:

In the cherry, plum, apple and pear, the observations made during the past season were largely upon the same trees as were used in 1899. It was thought that this method would render the results more comparable than if different trees were used. It has since appeared, however, that in the apple and pear other trees would have probably better answered our purpose. The reasons will appear later.

In both the plum[1] and cherry, embryo flowers began to be visible in buds taken July 5. In 1899 they were first visible in the plum in buds taken July 8, and in the cherry in those taken July 11.

[1] The varieties were King's Amarelle cherry (Prunus Cerasus) and Rollingstone plum (Prunus Americana). The trees of each were planted in 1892 on light clay-loam soil. The soil about the cherry tree was cultivated during the season of 1899 and in grass during that of 1900; that about the plum tree was mulched during both seasons. The Hoadley apple and the Wilder Early pear were used; the soil conditions were as described for the cherry.

In the apple, the attempt to discover the earliest appearance of the flowers the past season failed because the tree under investigation did not form any flowers. The method followed probably defeated its own end, for the plumpest buds were invariably removed for study, and these were the very ones that would have formed flowers first. The fact that the tree formed so many flowers during the season of 1899, and that so many buds were removed for study during that year greatly reduced the number of available buds for the flowers the past season, and those that might have formed flowers were doubtless removed before they had opportunity to do so. After searching in vain for flowers on this tree until September 5, buds were taken from other trees in the vicinity, and on one of these, viz., a Northwestern Greening, flowers were found quite well advanced.

The first evidence of flowers in the pear were found in buds taken September 6. In 1899 the first flowers were found in buds taken July 21. The flowers may have been belated the past season by the removal of the plumpest buds for study. The attempt will be made to repeat the observations with the apple and pear next season.

Evidence of a protracted period of flower formation in the apple and pear.—As was noted in our last report, the supply of flower-buds on the tree of the Hoadley apple, and of the Wilder Early pear selected for our investigation during the summer of 1899 did not hold out, so that it was necessary to begin on other trees during September. Every bud on these two trees that was sufficiently swollen to suggest that it contained flowers had been taken off for study. Of course we did not expect that these trees could bear a crop of fruit the following season. On looking them over early in March, however, it was observed that many of their buds had swollen to the size of flower-buds, and examination showed that they actually contained flowers. Fig. 59 shows the Wilder Early pear tree as it appeared during the blooming period the past season. Both this tree and the Hoadley apple tree produced an excellent crop of fruit. The conclusion is almost irresistible, therefore, that these trees, which had certainly commenced to form flowers in July, 1899, formed enough

FIG. 59.—Showing pear tree in bloom from which all flower-buds were thought to have been removed on Sept. 1, 1899.

flowers after September 1st to produce a good fruit crop. It is certain that during the present autumn (1900) flowers continued to form until October; see Fig. 60. There must either be two periods of flower formation in the apple and pear, or else the formation of flowers must continue from early in summer until cold weather. We cannot at present say which of these propositions is true, but indications seem to favor the two period hypothesis.

In certain apple trees of which the buds have been examined during the present autumn, the side buds on fruit-spurs that bore flowers last spring, and in some cases that bore fruit, have formed flowers. These buds were developed the past season. We

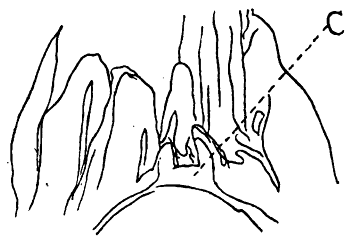

FIG. 60.—Flower-bud of Twenty-Ounce apple, taken Oct. 5, 1900. C. crown, showing incipient flower, magnified 25 times.

have been taught that the same branchlet of a fruit spur does not often fruit two seasons in succession. In our orchard many such have formed flowers two seasons in succession on trees of the following varieties: Bog (Russian), Early Sweet (Russian), Garfield, Judson, Kesha, Matthew, McMahan's White, No. 4 M. (Russian), Northwestern Greening, Oldenburgh (Duchess), Taylor's Crab, Zettle No. 3.

FORMATION OF FLOWERS IN THE PEACH.

Beginning July 5, samples of buds from a Bokara peach tree planted in the spring of 1898 were taken weekly and imbedded in paraffin for microscopic examination. The tree passed the severe winter of 1898–99 with little injury and was very thrifty during the past season. The first buds were taken before the side leaves of the trio that usually accompanies flower-buds had formed. After the side leaves commenced to form, only buds subtended by these were taken. Fig. 61 shows a vertical section through a trio of buds taken July 26. It should be remembered that in the peach the flower-buds grow, if at all, on either side of a leaf-bud, on shoots of the current season. In this illustration the side-buds, marked F, while each was destined to form a flower had it been permitted to remain on the tree, showed at this time no evidence of the forthcoming flower. They are presented only for comparison with others taken later.

Fig. 62 shows a vertical section of a side-bud taken September 14. In this, the crown (c) shows a decided thickening as compared with that of the side-buds of Fig. 61, which is undoubtedly an indication that the flower was soon to appear.

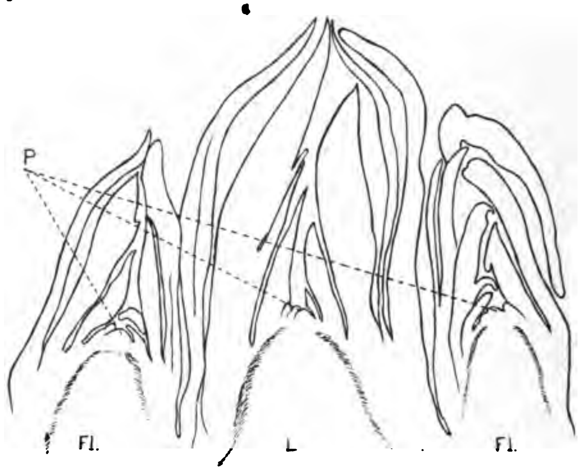

FIG. 61.—Section of trio of peach buds taken July 26, 1900. P, growing-points; L, leaf-bud; Fl, future flower-buds. Magnified 25 times.

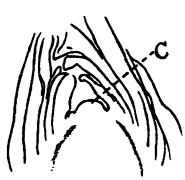

FIG. 62.—Section of flower-bud of peach taken Sept. 14, showing thickened crown at C. Magnified 25 times.

FIG. 63.—Section of flower-bud of peach taken Oct. 4, showing flower well developed. Magnified 25 times.

Others taken a week later showed unquestionable indications of flowers. Three weeks later, (October 4), the flowers appeared as in Fig. 63, in which the calyx, petals, stamens and pistil are clearly discernible. It appears, therefore, that in this variety of peach the flowers began to form about the middle of September the past season.

FORMATION OF FLOWERS IN THE STRAWBERRY.

Beginning July 5, samples were taken weekly of the runners and of the old strawberry plants from a matted row bed of the Clyde variety, planted in the spring of 1897. The leaves were picked off with the exception of the very smallest central ones, which, with the growing point which they inclosed and a small part of the stem whence they grew, were prepared for examination under the microscope. These prepared specimens were sectioned and examined from time to time, but no indications of flowers appeared until those taken on September 20, were reached.

In order to make the drawings below comprehensible, it is necessary to explain briefly the structure of the "heart" of the strawberry plant. The stem of the strawberry grows mostly underground, and from its summit the leaves grow, somewhat as the leaves of the beet grow from the so-called "crown of the root." The leaf-stalks have broad stipules at their base which wrap about the growing point at the center, whence the new leaves are formed. In sectioning vertically through the growing point, the embryo leaves wrapped about it are of course cut in all positions, hence it is impossible to trace in the thin sections any order in their arrangement. On this account most of

FIG. 64.—Section of "heart" of strawberry plant taken Sept. 20. C, crown, or growing point.

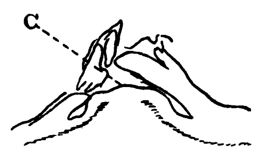

FIG. 65.—Section of crown of strawberry plant taken Sept. 20, showing early stage of flower formation. Magnified 25 times.

the foliage details are omitted in the drawings. The growing point, or, as we have called it in previous writings, the "crown" of the bud is the part in which we are interested, for it is here that the flowers appear. Fig. 64 shows a section through the axis of a plant taken September 20. It appears that the crown (c), while it is considerably broader than it was in plants taken earlier, presents a nearly regular segment of a circle. In Fig. 65, which is a section through the axis of another plant taken

on the same date, the crown shows an irregular outline. This was the first well-marked deviation from the nearly regular curve of the crown observed, and after developments show it to be a very early stage of flower formation. Fig. 66 shows a section through the axis of a young plant grown from a runner and taken September 27. In this, the crown shows a more decided deviation, and marks a slightly more advanced stage of flower formation.

FIG. 66.—Section of crown of "runner" plant taken Sept. 27. Magnified 25 times.

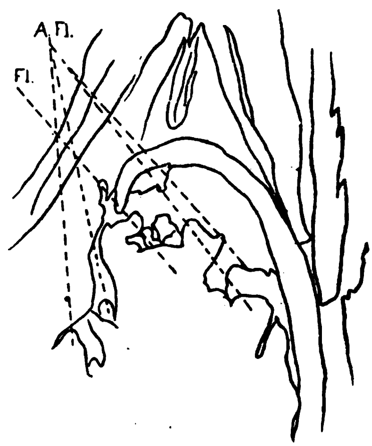

FIG. 67.—Section of crown of strawberry plant takan Oct. 4. Fl, terminal flower; A Fl, axillary flowers. Magnified 25 times.

Five plants wintered over from the previous year and five young plants were taken September 27. Four of each of these series showed clear evidence of flowers, indicating that at this time the formation of flowers was actively going on. A plant taken October 4, showed the flowers advanced to the stage indicated in Fig. 67, in which the terminal flower of the cluster (Fl) and several axillary flowers (A Fl) are readily located.

It would appear, therefore, that under our conditions the flowers in the Clyde strawberry did not begin to appear until the latter part of September. We hope to repeat these observations in future seasons in order to determine how much variation may occur in the time of appearance of the flowers. But our work has already gone far enough to emphasize the importance of keeping the strawberry bed free from weeds late in summer, of prevent-

ing the leaf blight so far as possible, and of keeping the soil moist by frequent cultivation, or irrigation if need be.

Do the flowers form in the runner plants as early as in the parent plant? Figures 68 to 71 show vertical cross-sections of a flower-bud of the parent plant, and of three runner plants grown in order from this plant, as indicated by the legends of the draw-

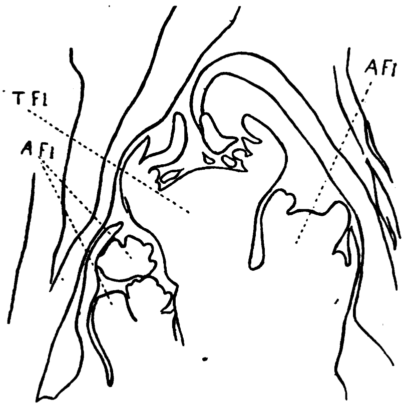

FIG. 68.—Showing section of flowers of strawberry plant wintered over from 1899, taken Oct. 11, 1900. T Fl, terminal flower; A Fl, axillary flowers. Magnified 25 times.

FIG. 69.—Section of first runner plant of a series of three grown from plant shown in Fig. 68. Taken Oct. 11. Magnified 25 times.

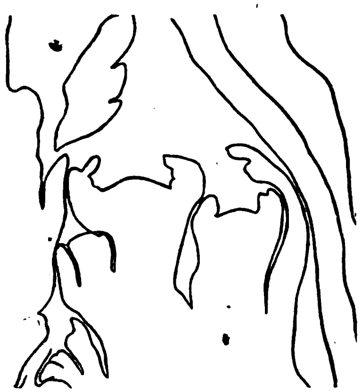

FIG. 70.—Section of second runner plant of the series. Taken Oct. 11. Magnified 25 times.

FIG. 71.—Section of third runner plant of the series. Taken Oct. 11. Magnified 25 times.

ings. It is of interest that there is very little difference in the stage of development of the flowers. The flowers appeared to start about the same time in the younger rooted runner plants as in the parent plant. This shows clearly that it is not age alone that determines the time of formation of the flowers.

AN EXPERIMENT IN PARTIAL DEFOLIATION.

On July 5, all of the leaves but one were removed from a number of fruit spurs of the pear, cherry and plum trees from which buds were being taken for our investigations. In the pear, each bud formed the previous season is surrounded by a rosette of leaves, hence each of the partially defoliated buds had one leaf left for nourishment. In the cherry and plum, on the other hand, each bud on a fruit spur is subtended by a single leaf, hence after the defoliation, only one bud on a spur was subtended by any leaf at all. Buds from these partially defoliated spurs were taken weekly, with the other buds, and were examined with the latter for comparison. When the defoliation was performed, it was supposed that no flower formation had commenced, but it later appeared that in the cherry and plum the flowers were already forming when the leaves were removed.

The effect of this partial defoliation was different from what was expected. Instead of preventing the formation of flowers in the pear, it actually hastened it. Three defoliated buds taken September 6, showed the flowers well advanced in two, while no evidence of flowers were found in undefoliated buds until the following week.

In the cherry and plum, the effect of the defoliation was less marked. As the flowers had commenced to form when the leaves were removed, they continued to develop in most cases. In one instance, the embryo flower appeared to have changed to a pair of bracts. The development of the flowers was slightly less rapid than in buds normally supplied with leaves, as was shown by the smaller size of the buds, and of the individual flowers within them, but the different parts of the flower appeared in their proper order and apparently in due time. This experiment proves, if any proof were needed, that a flower-bud does not depend for its development upon a subtending leaf, for in the plum and cherry several flower-buds developed with only a single leaf on the spur that bore them. It will be interesting to note if any of these defoliated buds will develop fruits next season.

DEDUCTIONS SUGGESTED BY THE FOREGOING INVESTIGATIONS.

Causes affecting the formation of flowers.—The direct cause or causes for the formation of flowers in our fruit plants is a subject of much interest and importance. Granting that every growing point of the stem has the power sooner or later to blossom as a part of the natural order of the plant's development, why are the flowers formed at particular seasons, and why do their numbers vary so greatly on the same plant from year to year? We are unable at present to fully answer these questions. The theory that has perhaps been most often accepted is that a check to growth induces the formation of flowers, and it is certain that flower-formation very often follows a check to growth. As was noted in our report for 1899, the flowers appeared in the cherry, plum, apple and pear about the time of the cessation of the annual growth.

But we have observed the past season that the flowers appeared in the peach and strawberry rather suddenly, and about the same time, during September. The question arises, what should have caused a check to growth at that season more than at an earlier or later date?

The following graphic diagram shows the minimum temperatures during September last at the Washburn Observatory. It appears that a decided decline in the minimum temperature occurred at almost exactly the time that the flowers commenced to form in the peach and strawberry. While the weather continued warm for more than a month afterward, the nights at this period became suddenly cooler, and with very few exceptions continued to be cool thereafter. A fall in temperature produces a check to growth, as truly as does a dearth of water, and it is not improbable that the advent of cool nights in autumn is as important a cause for the formation of flowers as the dearth of soil water that commonly occurs toward midsummer.

Do flower-buds ever revert to leaf-buds?—The growing point of a flower almost always perishes on the development of the pistil or pistils. Rarely it continues growth, and forms another flower, as is sometimes observed in the rose, or a leafy shoot, as has been observed in the pear. In the double-flowering cherry

excessive apple crops. If the seasonal conditions are exceptionally favorable to the formation of flowers, many buds of the current season, and practically all of those previously formed, will become flower-buds, and thus we have what amounts to two crops of flowers in one season. The proverbial failure of apple trees to bloom the year following an excessive crop is also explained by the using up of all the buds for flowers the preceding spring. It has been commonly assumed that the exhausted condition of the trees prevents them from forming flower-buds under such circumstances, but this is hardly tenable, because a tree too much exhausted to grow is more likely to form flower-buds than a more vigorous one.

It seems probable that varieties of the apple that bear annually are able to do so because they form flowers in buds of the current season, as is true of the cherry and plum. Indeed, this is almost the only explanation of continuous annual fruitage. One important secret of securing an apple crop every year is probably to select varieties that possess the property of forming annual flower-buds.

SUMMARY.

The anthers of the cherry or apple did not begin to swell perceptibly until after the maximum temperature had reached 70° F. The pollen mother-cells in the plum and cherry underwent some change before the temperature had exceeded 50°.

The embryo flowers appeared in the cherry and plum the past season very slightly earlier than they appeared in 1899. In the apple and pear the date of the first appearance of the embryo flowers the past season was not surely determined.

Embryo flowers sometimes form in the apple and pear in September as well as in July. The summer and autumn periods of flower formation may be distinct. The late-formed flowers in the apple and pear may produce, alone, a good fruit crop the following season.

The "side-buds" that developed the past summer on fruit-spurs of the apple that flowered last spring, formed embryo flowers in several varieties before the middle of October.

The embryo flowers began to form in a tree of the Bokara

peach in our Station orchard about September 14 the past season.

In the Clyde strawberry, the first indications of embryo flowers appeared September 20. In the rooted runner plants the flowers appeared at about the same time as in the parent plants.

Partial defoliation of the buds in the pear on July 5 hastened rather than retarded the formation of embryo flowers. In the plum and cherry partial defoliation of the fruit spurs just as the embryo flowers were commencing to form did not prevent their forming but slightly reduced their size.

The embryo flowers commenced to form in the peach and strawberry with the advent of cool nights in September.

Flower-buds probably do not often, if ever, revert to leaf-buds.

Flower-buds are apparently not structurally different from leaf-buds.

In the apple, a bud may form flowers the first, second or third season or even after that. If unduly shaded, it may never form flowers.

In favorable seasons for flower formation, many of the buds formed that season, and nearly all of those formed the preceding two seasons, that have not already flowered, will become flower-buds. An excessive apple crop results, which is necessarily followed by a light one, because the supply of reserve buds is exhausted.

SECOND REPORT ON EXPERIMENT IN PINCHING RASPBERRY SHOOTS.

E. S. GOFF.

In the Report of this Station for 1899 (pp. 275–282), was presented a preliminary report giving, with some other data, the yield of the first full crop from a plantation of the Gregg and Cuthbert raspberries, on which the shoots were pinched during growth in different ways. In the present report, we are able to offer the data of the second full crop from the same plantation.

The plantation comprises one-third of an acre of each variety. The plants are growing in rows seven feet apart, and were originally planted four feet apart in the rows. Each row originally contained 36 plants. The ground, which is a light clay loam, in a fair condition of fertility, has been well cultivated during the growing season since the plantation was started in the spring of 1897, and the plants have been well covered with earth each winter.

For the experiment, the plat of each variety was divided into three smaller plats, each of which contained three rows. Each of these three-row plats had one row that was left unpinched, one row of which the shoots only were pinched, and one row in which both the shoots and laterals were pinched. In the first plat of each variety, the shoots of the pinched rows were pinched as fast as they attained the height of 12 inches; in the second plat they were pinched as fast as they attained the height of 18 inches, and in the third plat, as they attained the height of 24 inches. The laterals were pinched as they attained the length of 12 inches. Up to the present season, only four shoots to a plant were permitted to grow, but there were indications that a larger number would give better results; hence the past season, five shoots to a plant were allowed to grow. The plantation has been carefully gone over at frequent intervals, and every shoot

in the pinched rows was pinched at nearly the designated height. The superfluous shoots and suckers were also removed at frequent intervals, and the amount taken from each row was separately weighed.

In the following table, the data for the past season are presented with the yield of the different rows calculated to the original stand of 36 plants. In certain rows one or more plants have perished, and in a few other rows an extra plant has inadvertently crept in. The calculated yield for the crop of 1899 is also given, and the average for the two seasons is given in the right hand column, bold face type.

Table showing effect of pinching the shoots on yield in the raspberry.

	Number of plants.	Number of canes.	Actual yield.	Yield calculated to 36 plants.	Calculated yield in 1899.	Average for two crops.
GREGG.			Ounces.	Ounces.	Ounces.	Ounces.
Shoots not pinched..........	35	123	973.3	1,001.0	1,952.8	**1,476.9**
Shoots pinched at 12 inches..	34	109	897.8	950.4	1,403.7	**1,177.1**
Shoots pinched at 12 inches; laterals pinched at 12 inches	36	115	1,117.1	1,117.1	1,880.9	**1,499.0**
Shoots not pinched..........	35	124	1,275.1	1,311.5	2,041.0	**1,676.7**
Shoots pinched at 18 inches..	36	116	1,232.9	1,232.9	2,178.1	**1,705.5**
Shoots pinched at 18 inches; laterals pinched at 18 inches	37	147	1,349.5	1,313.0	1,747.8	**1,530.4**
Shoots not pinched..........	36	116	1,228.5	1,228.5	1,738.8	**1,483.7**
Shoots pinched at 24 inches..	37	130	1,608.1	1,564.6	2,474.9	**2,019.8**
Shoots pinched at 24 inches; laterals pinched at 12 inches	36	151	1,457.7	1,457.7	2,014.1	**1,735.9**
CUTHBERT.						
Shoots not pinched..........	35	148	1,836.5	1,910.4	1,409.9	**1,675.2**
Shoots pinched at 12 inches..	37	145	1,463.1	1,423.6	1,448.4	**1,436.0**
Shoots pinched at 12 inches; laterals pinched at 12 inches	37	152	1,774.8	1,726.8	1,190.2	**1,458.5**
Shoots not pinched..........	37	141	1,815.1	1,766.0	1,574.2	**1,670.1**
Shoots pinched at 18 inches	37	160	1,578.1	1,535.4	1,409.9	**1,472.7**
Shoots pinched at 18 inches; laterals pinched at 12 inches	37	142	1,587.7	1,544.7	1,551.7	**1,548.2**
Shoots not pinched..........	35	126	1,345.9	1,384.3	728.8	**1,056.6**
Shoots pinched at 24 inches..	37	138	1,632.0	1,687.9	1,516.5	**1,552.2**
Shoots pinched at 24 inches; laterals pinched at 12 inches	36	136	1,415.3	1,415.3	920.1	**1,167.7**

In the above table the heavy lines vary in length to correspond with the average yield for the seasons of 1899 and 1900, as indicated by the figures in the right hand column.

It is to be noted from the above data that in the Gregg variety the largest two yields were from the two rows that were pinched at 24 inches high, and that the third largest yield was from the row pinched once at 18 inches high. In the Cuthbert, the largest two yields are from rows that were not pinched; the third largest yield is from a row pinched once at 24 inches.

The average of the three not-pinched rows of Gregg is 1,545.8 ounces. This yield is exceeded by the two rows pinched at 24 inches, and by the row pinched once at 18 inches.

The average of the three not-pinched rows of Cuthbert is 1,467.3 ounces. This is exceeded by the rows pinched once at 18 and 24 inches.

The pinching of the laterals appears to have been slightly detrimental to the yield, as compared with the once-pinched rows, in both varieties.

It seems best to defer an estimate of the amount of increase or decrease due to the pinching until we have harvested more crops from the plantation.

Effect of pinching upon the size of the berries.—Twice during the fruiting season one hundred berries, selected to represent as nearly as possible an average in size, from each row of the plantation, were weighed on a torsion balance in grammes. The data appear in the following tables:

Tables showing effect of pinching on the size of the berries.

GREGG.

Dates when samples were taken	July 5.			July 13.			Av. weight of the two samples.		
	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms
Shoots not pinched	126.5	127.2	142.5	122.0	127.5	130.5	124.0	127.0	136.5
Shoots pinched at 12 inches	119.5	......	......	108.5	......	......	114.0	......	......
Shoots pinched at 18 inches	......	131.0	......	......	109.0	......	......	120.0	......
Shoots pinched at 24 inches	......	......	122.0	......	......	125.5	......	......	123.5
Shoots pinched as above; laterals pinched at 12 inches	125.5	123.9	135.5	117.0	107.5	120.7	121.0	115.5	128.0

CUTHBERT.

Dates when samples were taken	July 11.			July 18.			Av. weight of the two samples.		
	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms
Shoots not pinched.............	159.5	177.5	174.2	150.7	157.0	169.0	155.1	167.2	171.6
Shoots pinched at 12 inches....	133.0	......	......	159.7	......	......	146.3	......	......
Shoots pinched at 18 inches....	......	157.5	......	......	161.5	......	.....	159.5	......
Shoots pinched at 24 inches ..	......	......	157.7	......	......	164.0	......	......	160.8
Shoots pinched as above; laterals pinched at 12 inches.	173.5	151.7	155.4	155.5	150.0	191.5	164.5	150.8	173.4

The three numbers in each column represent the rows of each of the three-row plats previously mentioned.

The average weight of 100 berries from the three not-pinched rows of the Gregg variety was 129.4 grammes. This weight was exceeded from a pinched row in only one case, viz., in the row pinched once at 12 inches. The average weight for all of the pinched rows was 120 grammes.

The average weight from the three not-pinched rows of the Cuthbert variety was 164.6 grammes. This was also exceeded from a pinched row in only one case, viz., from the row pinched twice at 24 inches. The average weight from all of the pinched rows was 159.2 grammes.

It appears, therefore, from the data that the pinching reduced the size of the berries in both varieties, and that the amount of the reduction was in proportion to the lowness of the pinching.

Effect of pinching on the growth of shoots and suckers.—The past season the superfluous shoots and suckers were removed from each row separately, and weighed, three different times, viz., on May 22, May 28, and June 18. The amounts thus removed from the different rows appear in the following table:

Table showing effect of pinching on the growth of superfluous shoots and suckers.

	Gregg.				Cuthbert.		
	Pinched twice.	Pinched once.	Not pinched		Pinched twice.	Pinched once.	Not pinched
	Oz.	Oz.	Oz.		Oz.	Oz.	Oz.
Pinched at 12 inches........	76.25	70.75	56.5	Pinched at 12 inches........	179.75	144.75	192.25
Pinched at 18 inches.........	61.75	48.0	39.25	Pinched at 18 inches........	173.25	197.0	195.5
Pinched at 24 inches.........	103.5	51.75	61.75	Pinched at 24 inches........	163.5	173.75	230.75
Average......	80.5	56.33	52.5	Average......	172.13	171.83	206.16

During the season of 1899, the growth of superfluous shoots was greatest in the pinched rows of both varieties. The past season it was greatest in the pinched rows of the Gregg, and greatest in the unpinched rows of the Cuthbert. It is possible that the pinching reduced the vigor of the latter variety to a degree that prevented the plants from producing the normal number of shoots. The suckers of the Cuthbert variety were weighed with the superfluous shoots.

For some reason, the growth of superfluous shoots and suckers during the past season was only about one-third as much as during the preceding season. The fact that five shoots were permitted to grow to each plant the past season, in the place of four as in the preceding season, doubtless explains this difference in part.

Summary.—Judging from the first two full crops, high pinching, i. e., at 18 to 24 inches, has apparently increased the yield of the Gregg raspberry, but has slightly decreased the yield of the Cuthbert. Low pinching, i. e., at 12 inches, has decreased the yield of both varieties. Pinching appears to have slightly reduced the size of the berries in both varieties. Pinching has evidently increased the growth of superfluous shoots in the Gregg variety. As noted in our last Report, pinching increases considerably the expense of covering the plants for winter, in both varieties.

We hope to carry this experiment through at least three more years.

THE RESUMPTION OF ROOT GROWTH IN SPRING.

E. S. GOFF.

In the report of this Station for 1898 (pp. 220–228), was published an article on the above subject, giving the result of an investigation made in the spring of that year upon the roots of a number of perennial plants. The winter of 1897–98 was unusually mild in the northwest, and as the result, the roots of all the plants examined were found to have started growth at the points where the growth ceased in autumn, i. e., at the apex of the ultimate branches.

The succeeding winter (1898–99) was, on the other hand, extremely severe in the northwest, and, owing to the absence of snow in southern Wisconsin during the coldest weather, the damage to the roots of trees and shrubs was very great.[1]

Examination in the spring of 1899 showed that the roots of only the hardiest plants, as the red and black currant, elm, mountain ash, and American arbor vitæ, started growth from their tips. The roots of all the fruit trees on our Station grounds were more or less damaged. Of many trees examined, a single root only of one Whitney crab tree was found to have started growth from the tip. The roots of other fruit trees were found injured in all degrees from total destruction to the destruction of the smaller root branches. The past winter (1899–1900) was rather milder than the average for this section, as is shown by the fact that the trees of the European and Japanese plums that were not too severely injured by the preceding winter, have borne a full crop of fruit. At one period, however

[1] See Bull. No. 77, Wis. Agri. Exp. Station.

(about Christmas), the temperature was quite low, with the ground uncovered by snow, during which the cracking of the soil in many places indicated rather deep freezing. The roots of a few apple trees were, therefore, examined last spring to ascertain to what extent they had suffered. It was found that very few rootlets were alive clear to the tip. Figures 73 to 75 were drawn from samples of roots washed out in the nursery.

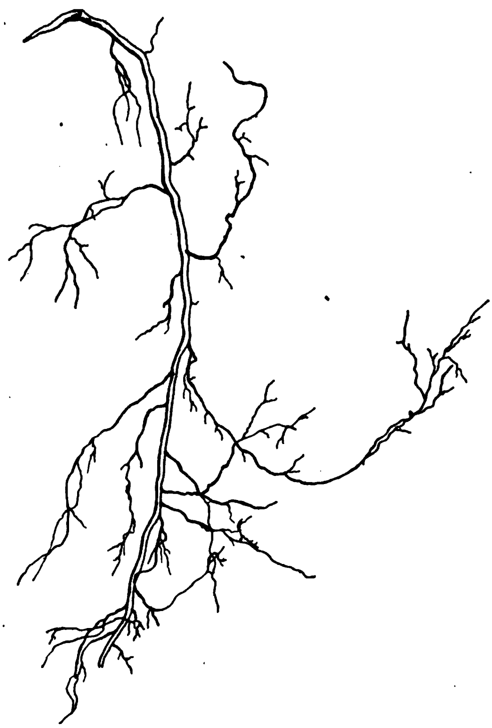

FIG. 73.—Showing portion of root of young apple tree in spring of 1900. The black rootlets were dead. Reduced one-half.

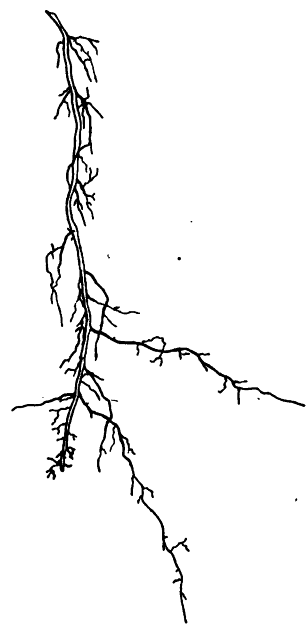

FIG. 74.—Another root of same character as Fig. 73. Reduced one-half.

In figures 73 and 74 the central root only was alive; in figure 75, the main root and branches were dead beyond the points indicated by the letter a, and the branches not lettered were wholly dead. The thick, unshaded roots were of new growth.

From these observations, in connection with those published in our Report for 1898, it is evident that in our climate the

question as to whether or not the roots of perennial plants resume growth in spring at their tips depends wholly upon the character of the winter, in many species. It is probable that more or less of root-killing occurs in all but the hardiest species in the average winter.

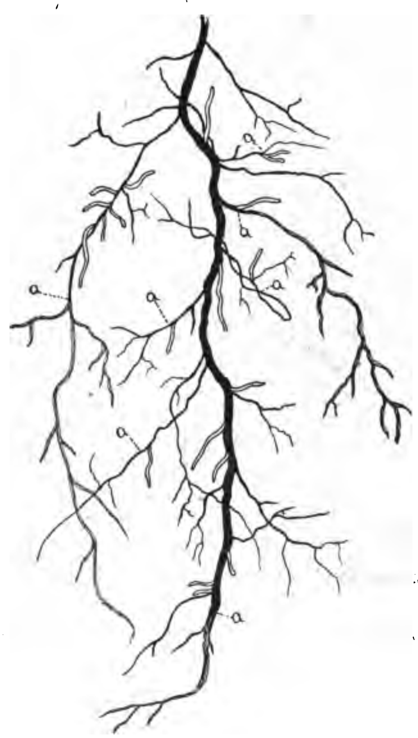

FIG. 75.—Another specimen of young apple root. The main root and branches were dead beyond the points marked A. The branches not lettered were wholly dead. The thick, unshaded roots were of new growth. Reduced one-half.

The extent to which the roots may suffer in winter without entailing death of the tree is surprising. In a tree of the Wilder Early pear, only two main roots were found to be alive in the spring of 1899; many others as large as these were dead. Yet this tree made a fair growth during the season of 1899, and the past season it bore a fine crop of fruit. A considerable number, of trees in the Station grounds, and in the near vicinity, that survived during the summer of 1899 and the past winter, have

since succumbed, being starved, no doubt, by their greatly damaged root system. Figure 76 shows a tree of the Oldenburgh apple which was photographed the first week of last August. It is evident that this tree is rapidly dying.

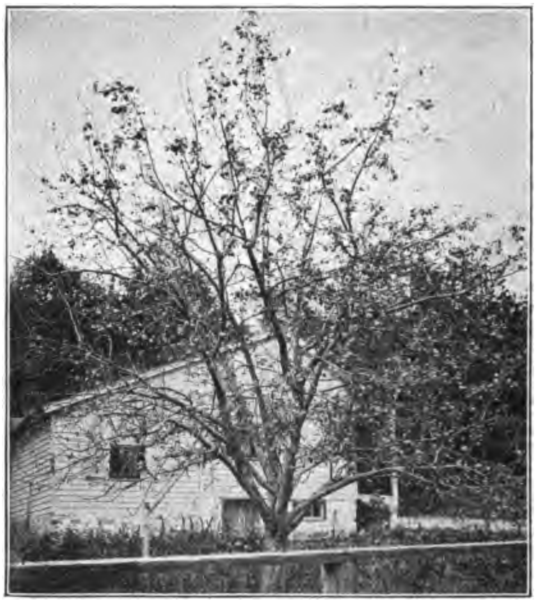

FIG. 76.—Showing tree of Oldenburgh apple dying during season of 1900 as result of injury to roots sustained during winter of 1898–99.

THE EFFECTS OF CONTINUED USE OF IMMATURE SEED.

E. S. GOFF.

I. IN THE TOMATO.

The report of this Station for 1893 contains an article entitled "A Breeding Experiment with Tomatoes," which is a record of an experiment in growing a stated variety of the tomato through six generations from decidedly immature seed. The effects upon the plant were very striking and were manifested in a marked increase in earliness of ripening and in prolificacy, with a decided decrease in the vigor of the plant.

Beginning with 1892, a duplicate of this experiment was undertaken including the same variety and two others. This second experiment has been continued, with one of the three varieties, up to the present year. The report of this duplicate experiment is here presented. As will appear, the effects upon the plant have been strikingly unlike those of the first experiment.

The method of conducting this experiment has been as follows: In the fall of 1891, two samples of seed were saved from an apparently healthy plant, each of the Cook's Favorite and Little Gem tomatoes. One of the samples in both varieties was from fully matured fruits and the other was from fruits that had not commenced to redden. At the same time, three samples of seed were saved from a healthy plant of the Potomac variety. One of these was from a fully matured fruit, a second from a fruit that had just commenced to redden, and the third from a fruit that showed no indications of reddening. Seeds from each of these seven samples were planted the following spring, and one row of plants fifty feet long from each sample was planted in our Station garden. As the fruits ripened they were gath-

ered from each row separately, wiped clean, the calyx was removed if it adhered, and the fruits were weighed on a torsion balance that is fairly accurate to the tenth of a gramme. Before the end of the fruiting season, other samples of seed were saved for the next year's crop; the mature seed being taken from the plants grown from the mature seed, and the immature seed from the plants grown from the immature seed. When hard frost became imminent, the immature fruits still remaining on the vines were picked and weighed, and the vines were weighed for each row separately. The same system was followed with the three varieties for five years, and with the Potomac variety three years longer. In the following table are given the average yield of fruit per hundred pounds of plant, the average percentage of the crop that ripened and the average percentage of the ripe fruit that was gathered in the first four pickings, for all of the years that these data were preserved.

The first average shows the effect of the seed selection upon the prolificacy of the plants and the second and third show its effect upon the earliness.

Table giving data of experiment in growing the tomato from mature as compared with immature seeds.

Variety.	Selection of seed.	Yield of fruit per hundred lbs. of vine.		Per cent. of the crop that ripened before frost.		Per cent. of the fruit gathered in the 1st four pickings.	
		No. of years.	Average yield.	No. of years.	Average per cent.	No. of years.	Average per cent.
			Lbs.				
Cook's Favorite.	Mature seed...	5	78	4	41	5	10
Cook's Favorite.	Immature seed	5	42	4	35	5	9
Little Gem......	Mature seed...	5	88	4	36	5	8
Little Gem......	Immature seed	5	110	4	41	5	7
Potomac	Mature seed...	8	274	7	59	8	17
Potomac	Slightly immature seed.....	8	228	7	59	8	12
Potomac	Very immature seed..........	8	235	7	59	8	17

A brief study of the table shows that the use of the immature seed has had no uniform effect in this second experiment on the prolificacy or the maturing season of the plants, and no effect could be seen at any time upon the vigor of the plants. It seems scarcely credible that this statement can be true in view of the decided immaturity of the seed used, and of the striking results that followed the first experiment. The data for both experiments have been very carefully compiled and the computations have all been verified. The weighings were all performed, with the exception of two pickings only, by my assistant, Mr. Cranefield, or myself, and neither of us can offer the slightest excuse for rejecting any of the data. We can only conclude that, in the tomato, the use of immature seed may under some conditions produce striking effects upon the plants, and that under others, no effects are discernible, unless the use of the immature seed is continued longer than eight years.

II. IN INDIAN CORN.

In the spring of 1896 an experiment was started in growing Indian corn from seed gathered at varying stages of maturity, to ascertain if any advantages are likely to follow gathering the seed before fully ripe.

The variety grown was a strain of the King Philip (flint) corn. The crops have all been grown on good soil, and have received good culture. The earlier-picked samples have been gathered about Aug. 20, and from that time, at intervals until the corn was fully matured. As appears from the table below, the number of selections has not always been the same. The gathered seed ears have been left unhusked until dry, but no artificial heat has been used in the drying. The different selections of seed have been planted in adjoining plats, the usual area of each being ten rows, fifty feet long. The following table gives the data from this experiment. As the number of stalks grown in the different plats was not uniform, the yields given in the table have all been calculated to a uniform number of stalks, to make the results more comparable. The table is divided at the center, from left to right, to accommodate the page.

Table showing data of experiment in growing Indian corn from seed gathered at varying stages of maturity.

YEAR.	FIRST SELECTION. (Most immature.)			SECOND SELECTION.			THIRD SELECTION.		
	Yield of ears.	Yield of stalks.	Yield per 100 lbs. of stalks.	Yield of ears.	Yield of stalks.	Yield per 100 lbs. of stalks.	Yield of ears.	Yield of stalks.	Yield per 100 lbs. of stalks.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1896	210.2	610.2	34	251.1	481.2	52	258 0	541.3	47
1897	196.4	398.6	49	214.2	435.8	49	206.0	393.7	52
1898	429.9	672.8	63	461.7	887.8	52	507.6	1,082.8	46
1899	258.0	586.7	43	....	....	....	....	....	....
1900	206.5	739.0	27	....	....	....	....	....	....
Average	262.2	601.4	43.6	309.0	601.6	51	323 9	672.6	48.3

YEAR.	FOURTH SELECTION.			FIFTH SELECTION.			SIXTH SELECTION. (Fully matured.)		
	Yield of ears.	Yield of stalks.	Yield per hundred lbs. of stalks	Yield of ears.	Yield of stalks.	Yield per hundred lbs. of stalks.	Yield of ears.	Yield of stalks.	Yield per hundred lbs. of stalks.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1896	....	....	....	283 4	529.8	53.	269.0	643.9	41.
1897	....	....	....	189.7	462.5	41.	224.2	531.9	42.
1898	526.8	920.0	57.	494.8	1,138.6	43.	491.6	1,047.4	46.
1899	....	....	....	....	....	....	318.1	666.6	47.
1900	....	....	....	....	....	....	191.7	726.5	26.
Average	526.8	920.0	57.	322.6	710.3	45.6	298.9	723.2	40.4

Effects upon the yield of corn and stalks.—It is worthy of note that in the three seasons in which more than two selections of seed were made, the largest yield was grown from a selection at a medium stage of maturity in two of the three seasons. In the average for all of the years, the medium mature seed gave the largest yield of corn and stalks. Some farmers are of the opinion that seed corn should not be fully ripe when gathered, and these results tend to confirm that opinion. It is noticeable also that the very immature seed gave a smaller yield both of

corn and stalks than the fully mature seed, in every case except in the crop of 1900. It is proper to add that the crop grown from the mature seed the past season was somewhat damaged while the plants were young by soil washing in from adjacent higher ground.

Effects upon the season of maturity.—Observations were made from time to time on the comparative stage of maturity of the different plats. In the season of 1896 the corn grown from the seed gathered at the second picking showed the most advanced ears. In 1897 that grown from the third and fourth pickings was called most advanced. In 1898 that from the first and second selections was pronounced earlier in maturity than the crops from the later pickings. In 1899 the ears were watched as the husks began to whiten, and the number that had commenced to whiten was counted in the plats grown from the immature and mature seed on three different dates with the following results:

	Immature seed.	Mature seed.
Total number of ears	293	310
Per cent. beginning to whiten Aug. 20	18.4	5.8
Per cent. beginning to whiten Aug. 28	35.8	14.5
Per cent. beginning to whiten Aug. 29	63.5	56.4

In 1900 the ears of which the silks were beginning to brown were counted for both plots on July 26. Compared with the whole number of ears, it appeared that 17 per cent. of the ears showed brown silks in the plat grown from the mature seed, and 20.1 per cent. in the plat grown from the immature seed. It appears, therefore, that the corn grown from the very immature seed was slightly earlier than that from the fully mature seed.

Summary.—In an experiment extending over five to eight years in three varieties of the tomato, no perceptible results followed the use of very immature seed.

In an experiment extending over five years with a variety of flint corn, very immature seed gave smaller yields of corn and stalks and slightly earlier maturity than fully mature seed. The largest yields of corn and stalks were from corn gathered slightly immature.

DURATION OF THE GROWTH PERIOD IN FRUIT TREES.

F. CRANEFIELD.

Observations have been conducted during the past two seasons for the purpose of determining the length of the growth period of apple, pear, cherry and plum trees.

The time when growth begins in the spring may be readily observed, but how late in the season it continues, the rate at which it proceeds, and how it is affected by conditions of moisture and temperature is not so well known. It is commonly stated that in this region trees complete their growth by midsummer, the remainder of the season being expended in maturing the growth. The results here given seem to confirm this opinion.

The work was begun May 8th, 1899, when one apparently healthy tree, each of apple, pear, cherry and plum, growing in the Station orchard, were selected and two shoots of each were measured at intervals of two to four days until no further increase in length could be observed. A flexible pine rule $\frac{1}{8}$ inch by $\frac{1}{2}$ inch and of the desired length was used in measuring, and the measurements were recorded in millimeters, twenty-five and one-half millimeters being approximately equal to one inch.

The age, approximate height and variety of the different trees is as follows:

Apple: Gideon variety; both seasons; 10 years old; about 12 feet in height; bore a light crop in 1899 and a very heavy crop in 1900; cultivated both seasons.

Pear: 1899; Vermont Beauty variety; 10 years old; about 12 feet in height; bore light crop; growing in sod; did not blight.

Pear: 1900; Sudduth variety; 4 years old; about 5 feet in height; no fruit; cultivated; no blight.

Plum: 1899; Rollingstone; 10 years old; 8 to 10 feet in height; bore medium crop; heavily mulched.

Plum: 1900; Hammer; 6 years old; 6 to 8 feet; bore heavy crop; mulched.

The following diagrams (pp. 302–303) show the total increase in length of the shoots, the rate of growth, and the time when growth ceased. The date of each measurement is noted at the top of the page and the number of millimeters at the left, each space representing 10 millimeters. The curved line will thus represent the rate of growth. In the smaller section at the bottom the rainfall in inches is represented by vertical lines and the average maximum temperature for the different periods, by numerals.

As may be seen from these diagrams, no increase in length occurred in 1899 in any case after June 23d, while the pear did not grow after June 1st nor the cherry after May 27th. The trees were observed closely after these dates to note if any branches were growing, as judged by the appearance of the terminal buds but no indications of growth were observed. Extended observations of several hundred trees, throughout July and August, showed plump terminal buds in every case and therefore no indication of growth. The same was true of fruit trees in the vicinity of the Station grounds.

It may be said, then, that the majority of fruit trees in this vicinity completed their growth in the summer of 1899 by July 1st, and but few continued to grow after June 1st. In this connection, however, it is well to state that these observations were taken after one of the most severe winters ever known in Wisconsin.

As may be seen from Fig. 78 growth ceased the past season, in the apple and plum trees June 29th, in the pear trees June 18th and in the cherry July 10th. This refers only to the trees of each species previously mentioned, as other trees in the orchard continued to grow until Oct. 1st, at which time most of the terminal buds examined appeared to be plump and fully formed.

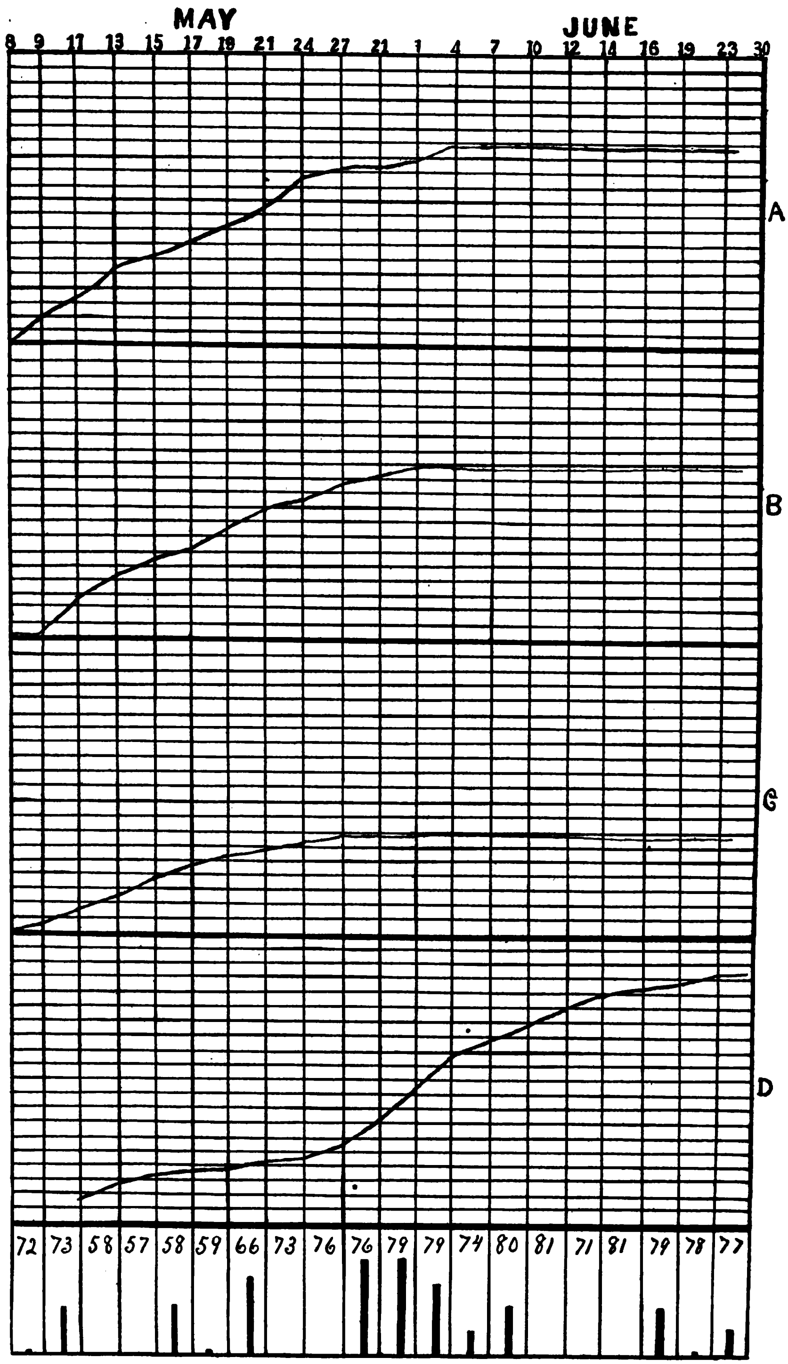

FIG. 77.—Illustrating the rate of growth of twigs in 1899. The numerals at the top represent the dates of measurements and the vertical spaces millimeters, each space representing 10 millimeters. The heavy vertical lines in the larger space at the bottom represent the rainfall for the different periods; the numerals above these lines representing the average maximum temperature. A represents growth of Gideon apple; B. Vermont Beauty pear; C. Lutovka

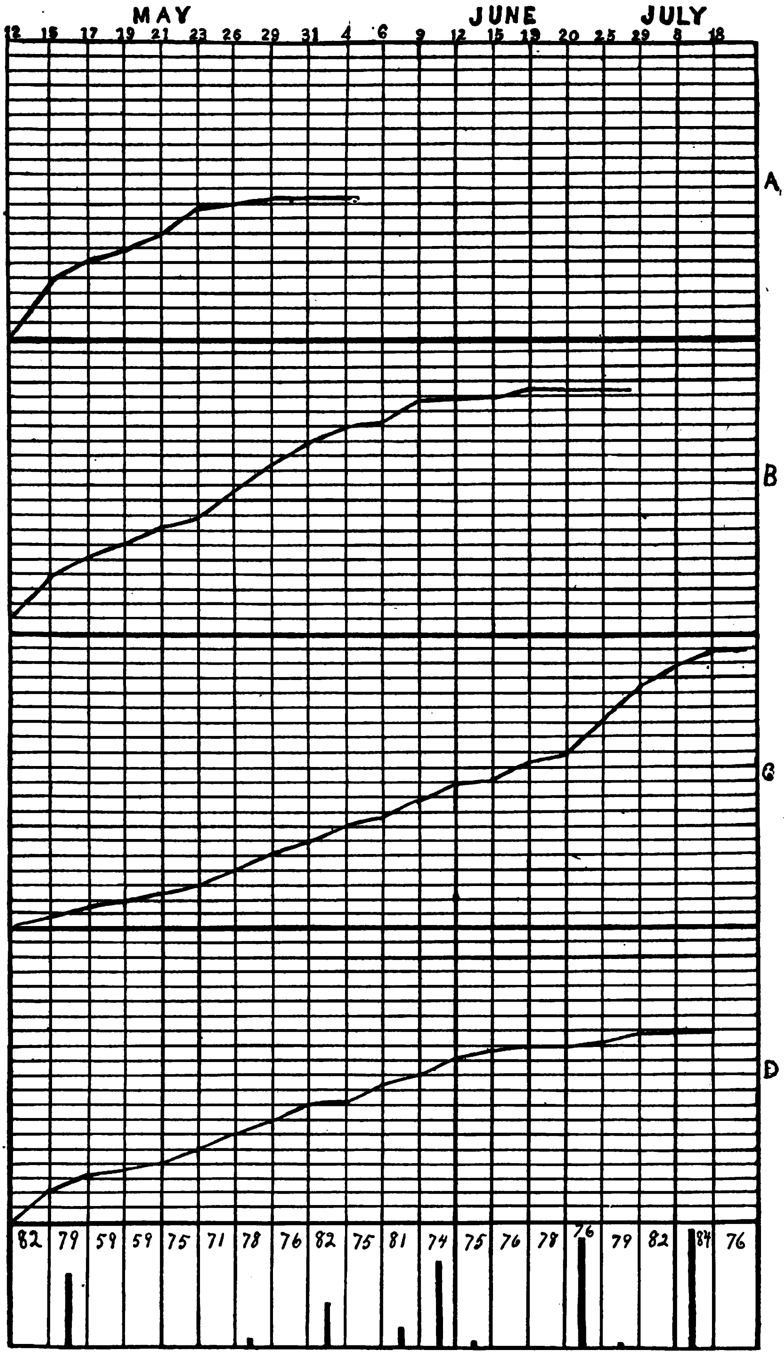

FIG. 78.—Illustrating rate of growth of twigs in 1900. Legend similar to Fig. 77,

Second growth.—Observations were continued after the dates above mentioned, and while no indication of growth appeared in the trees selected for measurements, the somewhat surprising fact was disclosed that many trees were making a new or "second" growth from the recently-formed terminal buds, i. e., the leaf buds formed at the tips of the shoots during the season of 1900.

On some trees a majority of the terminal buds had started into growth while in others only three or four buds had developed a second growth. Several of these second-growth shoots were measured as in the previous case and were found to be growing rapidly, in some cases at the rate of one-half inch per day. This second growth began about July 15th and continued in some cases until September 18th, although most of the second-growth shoots ceased growing about September 10th, when fairly plump terminal buds were visible. Many of the second-growth shoots measured ten inches and some twelve inches in length.

Three hundred and twenty-five trees were observed, two hundred and twenty-two growing in sod and the remainder in cultivated land. Sixty-six per cent. of the cultivated trees and twenty-one and one-tenth per cent. of the trees in sod made a second growth.

No second growth was found in the cherry orchard, consisting mainly of Russian varieties, nor on any native plum trees, but all of the Japan plums developed a strong second growth. Among the Japan plums are the following varieties: Strawberry, Red June, Wickson, Maru, Abundance and Burbank. Of eight pear trees observed, two made a strong second growth while other trees of similar varieties and growing under like conditions failed to start.

Many apple grafts, top-worked on orchard trees in the spring of 1900, continued to grow several weeks later than the stocks. No flowers opened at any time, showing that the leaf-buds, only, developed and of these only the terminal buds.

In the following table is given the total rainfall in inches for both seasons from May to September, inclusive; also the average maximum temperature for these periods. As may be seen from this, the total rainfall for 1900 was a trifle less than that for

1898. When taken by months, however, there appears a difference. In 1899 the rainfall in May and June was greater than in the two following months, while in 1900 the conditions were reversed. These conditions may account for the second growth of the trees in 1900.

Table showing the total rainfall in inches and the average maximum temperatures for the months of May to September, inclusive, 1899 and 1900.

	1899.		1900.	
	Rainfall in inches.	Av. maximum temperature.	Rainfall in inches.	Av. maximum temperature.
May	4.92	67.4	1.86	70.9
June	2.64	78.4	3.20	78.3
July	3.29	81.1	6.91	75.0
August	3 57	73.6	2.72	83.2
September	3.25	68.9	2.89	55.2
Total	17.67	....	17.58	....

Investigations were conducted in connection with the observations on growth duration to determine, if possible, the earliest and latest date on which the bark would peel or separate from the wood readily enough to permit of budding and if this condition prevailed continuously throughout the season; also to learn if the bark "set" or tightened earlier on the smaller or larger branches. The method employed in the season of 1899 was to make "T" cuts similar to those employed in budding, in branches of various sizes on trees of the various species previously mentioned. Several thousand of such cuts were made during the season and as a result it was found that the bark could be peeled readily at any time on both large and small branches up to August 15th; that after this date the bark was set on many of the smaller branches although it could be easily peeled on the larger ones; that no difference appeared to exist between trees of different ages; that cultural conditions appeared to exert no influence; that a wide difference existed between trees of the same variety, age and external appearance, and that the differ-

ence was often greater between different branches of one tree than between different trees.

A slightly different method was employed the past season. Instead of making an incision as for budding, the bark was separated entirely from a short section of the branch as is done with a willow branch when making a willow whistle. Fig. 79 shows one of these whistles cut September 8th. Branches were cut from various trees at intervals of seven to eight days from May 10th to Oct. 3d. No difficulty was experienced in slipping the bark from the wood in any case up to Sept. 15th. On this date it was impossible to slip the bark from branches one-half inch or less in diameter while on larger branches it sepa-

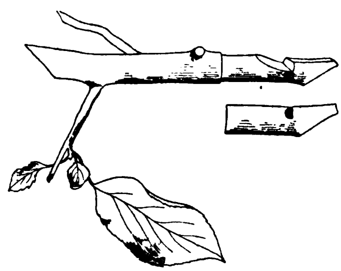

FIG. 79.—Showing method of making "whistles" in bark-peeling experiment.

rated easily in most cases. On Sept. 25 a number of good whistles were made but it was found to be necessary to take larger branches than on the previous date as the bark had tightened on all branches tried that were less than three-fourths inch in diameter. On Oct. 3rd the bark appeared to be set on all branches both large and small. From this it would appear that the time when the bark sets varies with the season, as it could be peeled one month later in 1900 than in 1899. It would also appear that it sets first on the smaller branches.

DURATION OF ROOT GROWTH.

The duration of the period of root growth in trees is a matter of interest. How early in the season does the growth of the root begin? How late does it continue? Does root growth continue after twig growth has ceased?

An attempt has been made the past two seasons to answer these and other questions as far as related to certain fruit trees. Prof. Goff has determined[1] that root growth in the apple and certain other plants precedes leaf formation. In order to study the continuance of root growth the following experiments were undertaken: On May 25 a narrow trench was dug alongside one tree, each of apple, pear, plum and cherry; in most cases about two feet from the trunk and long and deep enough to sever a number of roots. The trenches were then refilled with well-enriched earth. It was presumed that rootlets would form

FIG. 80.—Showing the growth of roots of Lutovka cherry from Aug. 22 to Oct. 6.

at the ends of the several roots and push out into the rich earth as long as any root formation was taking place. On July 10th the earth was carefully washed out, by means of a fine stream of water, in order to observe the growth of roots, and it was found that active root formation had occurred in all cases. The most extensive root growth was found in the cherry, the next in order being the plum, with the pear next and the apple least. The new growth of roots was then cut off and the trenches refilled.

[1] Ann. Rep. Wis. Exp. Sta., 1898, p. 220.

The washing operation was repeated Aug. 22nd with similar results.

No growth of twigs had occurred on any of the trees later than July 1st as determined by a system of measurements similar to that employed in the previous experiments. The roots were examined again Oct. 6th and it was found that all had made a good growth since Aug. 22d, as shown by Fig. 80, which shows the extent and distribution of the roots formed from the cut end of one of the cherry roots, and were evidently still growing as shown by the white root tips.

A DESCRIPTION OF THE NEW CHEESE CURING ROOMS AND THE FOREIGN CHEESE MAKING ROOMS.

E. H. FARRINGTON.

Up to the present season the cheese rooms of the dairy building have been provided with facilities for giving instruction in cheddar cheese making only.

The Swiss, brick and Limburger cheese industry is an important one in this state, and our equipment has now been enlarged so that we may be able to give instruction in the processes of making these foreign cheeses. In this addition, which extends partially into the side hill, new cheese curing rooms have also been provided, and the basement floor is connected with the main dairy building by a tunnel. This tunnel serves as a passageway from the cheddar cheese making room of the main building to the press room and the curing rooms of the new building.

The tunnel is twenty-eight feet long, six feet wide and six feet six inches high.

The main floor of the new building is forty-seven by fifty-seven feet in size. It is below the surface of the ground, as shown in the south elevation diagram, Fig. 82. The rooms on this floor are nine feet high and eight feet below the surface of the ground on the side farthest into the hill, the east side. The slope of the hill, however, is such that light enters the west rooms on the north and south sides through windows at the areas, shown on the plan of this floor, Fig. 81. The dimensions of the rooms are as follows:

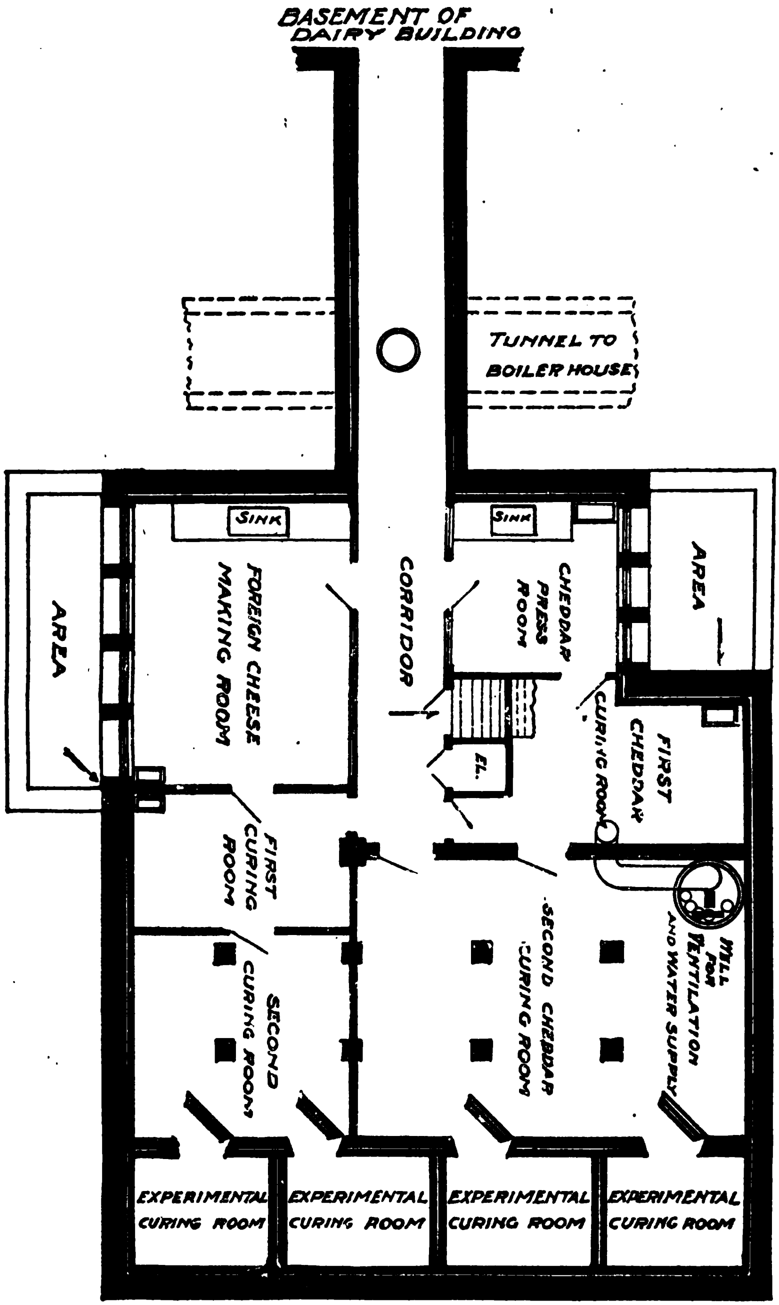

FIG. 81.—Plan of cheese curing rooms and foreign cheese making rooms.

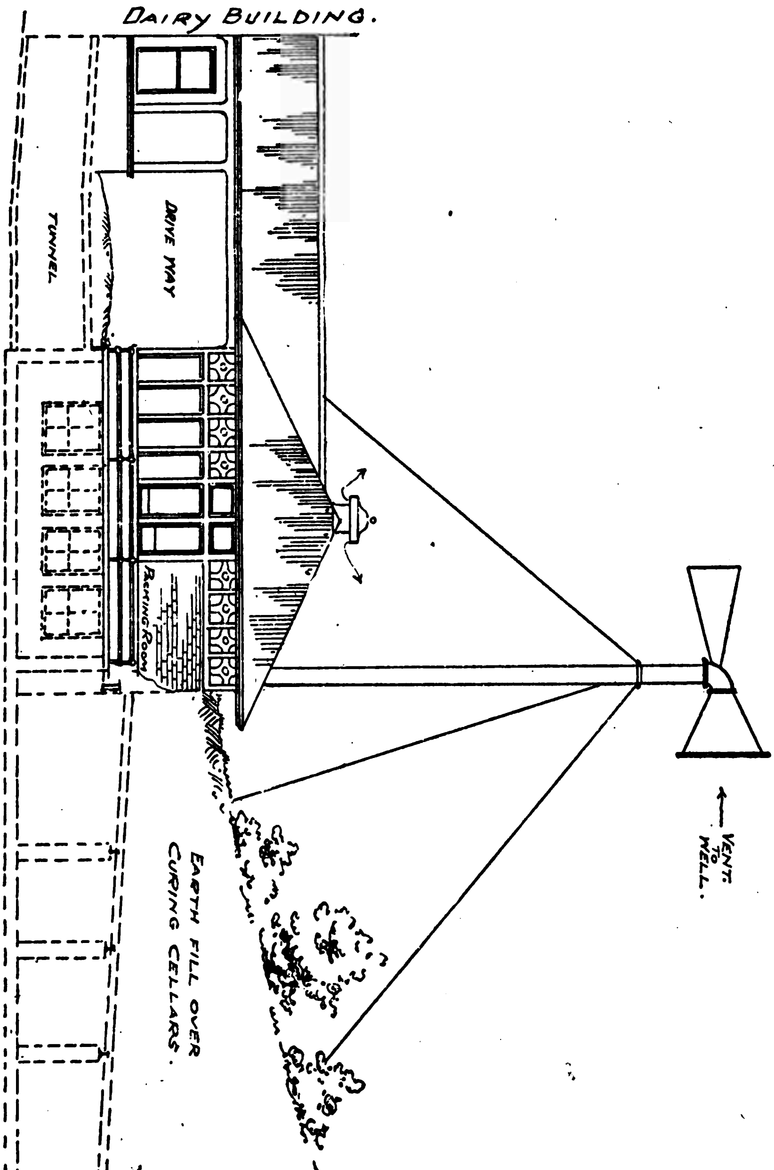

FIG. 82.—South elevation of Fig. 81.

Cheddar press room	12 ft. by 12 ft
First cheddar curing room	11½ ft. by 20 ft
Second cheddar curing room	20 ft. by 27 ft
Foreign cheese making room	16 ft. by 20 ft
First curing room (salting room)	10 ft. by 16 ft.
Second curing room	13 ft. by 16 ft.
Experimental curing rooms, each	8 ft. by 10 ft.

All the rooms have Portland cement floors except the foreign cheese making room, which has a tile floor and yellow tiled sides two feet up from the floor.

THE WELL AND SUB-EARTH DUCT.

In the second cheddar curing room the plans show the location of the well used for ventilation and water supply. The well is four feet in diameter down to a depth of 40 feet and to this depth it is lined with a four-inch brick casing laid in cement. An 18-inch galvanized iron pipe conducts the outside air from 20 feet above the roof of the building to the mouth of the well. At the basement floor the well is covered with a concrete top carried on steel and a cast iron man-hole gives access to the well. Three feet below the surface of the floor five 6-inch and one 10-inch vitrified pipe elbows are carried through the wall of the well, and these lines of pipe are extended under the floors to each of the curing rooms where they are brought up into the room and supplied with a damper and a register. Inside the well these elbows are connected with galvanized iron pipes which extend to within one foot of the bottom of the well. The fresh air blowing into the hood of the 18-inch pipe 20 feet above the roof passes to the bottom of the well and in cooling deposits its moisture; the dry, cool air then passes through the pipes and is distrubuted to the different rooms. In each room so supplied with air a corresponding vent duct passes up through a large ventilator in the roof, thus completing the system of circulation and giving dry, cool rooms. This vertical sub-earth duct furnishes an illustration of this method of regulating the temperature and moisture of cheese curing rooms. Each room is provided with heat, cold and ventilation which can be changed and regulated as desired.

An inexhaustible water supply is obtained from the well by means of a 6-inch iron pipe driven to a depth of 150 feet from the floor of the basement and 30 feet into the Potsdam sandstone.

METHOD OF HEATING.

The experimental curing rooms are heated by means of hot water coils, the water being heated by a gas lamp so as to readily control the temperature. The second cheddar cheese curing room and the second foreign cheese curing room will be heated by direct steam radiation. All the other rooms on the basement floor are heated by a direct indirect system of heating, by which means fresh air is brought in from the outside, then passes over the radiators and out into the room.

METHOD OF ROOFING THE CELLAR.

The earth over the cellars is supported in the following manner: On top of the brick walls and stone columns a system of steel girders and steel beams is laid, it being strongly riveted and rodded together. Between the steel beams brick arches are built and the whole is covered to a depth of four inches above the top of the arches with the best Portland cement concrete. This entire roof has a slope towards the east to discharge all water rapidly. Above this concrete the earth is filled in to the original grade.

FIRST FLOOR.

Near the central corridor an elevator and stairs lead up to the first floor, which is to be used for a store room and cheese boxing room. This floor is built over the west side of the basement floor only, as shown in Fig. 82, and is 29 by 39 feet in size.

RECORD OF THE UNIVERSITY DAIRY HERD.

W. L. CARLYLE.

In the last annual report of this Station is given the initial yearly record of a number of the cows in the University dairy herd. As stated in that report, one of the objects sought in keeping this herd at the Station is the determination of the comparative merits of the so-called special-purpose dairy cow and of the dual-purpose cow for milk and butter production. Our cows have completed another year's work, during which we have endeavored to be even more accurate than before in weighing all of the feed, except the pasturage, and in keeping records of the details of the work in the dairy barn. In many respects the work of the past year has been more satisfactory than the year preceding. In a measure we have been able to control the time of freshening of the cows so that they might come into milk at the most favorable time, and we have also been able to so feed and care for the majority of them previous to and at the time of calving that they have been in much better condition for the yielding of a largely increased milk and butter product for the year. Not only this, but the cows having grown accustomed to their surroundings, to the visitors and the frequent weighings, etc., have been more contented as a whole, which has contributed not a little to the year's success in surpassing the former year's work. As far as possible we have aimed to let each year of the record cover one period of lactation, for which reason some months of the records given last year are included in a number of the records given this year. In all cases, however, the feed is charged for the entire year, even where the cows were only milked for nine or ten months of that period.

Again the writer must record his surprise and that of the herdsman, J. R. Danks, to whose unremitting care and attention much of the success of the herd is due, at the large amount

of milk and butter given by the large and heavy grade Shorthorn cows of the dual-purpose type.

Care and management.—All of the cows in the herd received the same attention and they were fed and handled as carefully as was possible. Beginning early in October they were kept in the barns every night and let out during the day, until the weather became so severe that the ground was frozen, when they were turned into the yard for a portion of every bright day. This was continued during the early part of the winter, but later they were confined in their stalls during the day and only turned into the yard for a short period on two or three days of every week.

Their treatment during the summer was that known as partial soiling, that is, they were pastured every night, and for a part of each day during the spring and early summer. They were allowed corn silage every day until well into June, when they were fed a rotation of soiling or green crops in the barn. These included peas and oats sown thickly at two successive periods, vetches and oats also sown in successive periods, and oats sown alone, followed by early sown Dwarf-Essex rape, early planted dent corn, sorghum, two varieties of millet, Giant fodder corn, evergreen sweet corn, and last of all, late sown rape. These crops were all grown on one-eighth and one-quarter acre plots and were cut and hauled to the barns every day as needed, supplying ample succulent green feed at all times. Some of the large grade Shorthorn and Holstein cows ate large quantities of these green feeds, while the smaller cows with less capacity consumed much less the amount eaten per day by the different cows, ranging from 45 to 65 pounds each. During the winter and spring months, when they were receiving silage, the same was true, except that the amount eaten by the different cows varied from 38 to 56 lbs. per cow, according to her size and capacity.

In Fig. 83 is shown the grain truck and apparatus used for weighing each feed of grain or concentrated feed of any kind given the cows. It was a surprise to learn how very little time was expended in weighing each cow's feed when it was done in this way. The feeder very soon became an expert at estimating each cow's feed in the feeding pail before weighing it, so that little time was lost. Fig. 84 shows the truck used in convey-

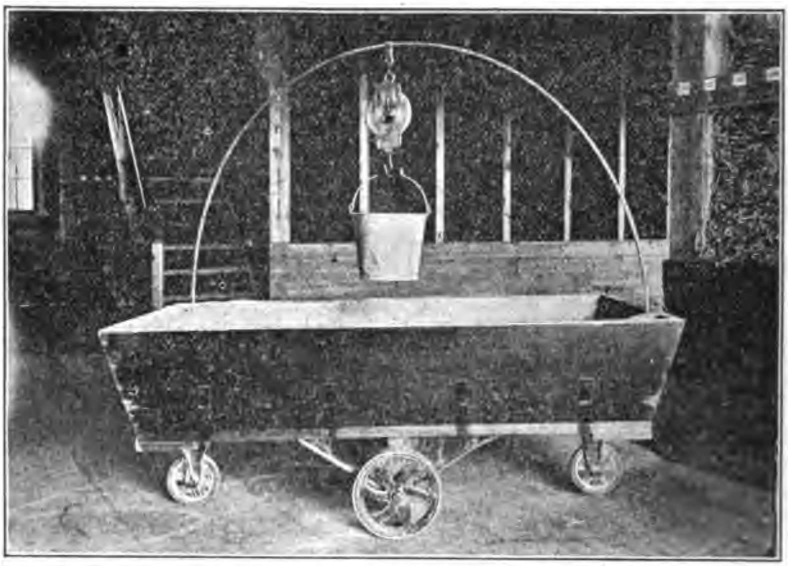

FIG. 83.—Feed truck and apparatus used for weighing each feed of grain or concentrated feed of any kind given the cows.

FIG. 84.—Truck used in conveying all the roughage to the cows, and the apparatus for weighing it.

ing all the roughage to the cows and the method of weighing it. We found that with silage or cut fodder of any kind it was just as convenient to fill the basket on the counter-spring scales as to fill it while resting on the floor. With uncut hay and with the soiling crops it was somewhat more trouble to weigh each feed to every cow. Our aim in all cases was to feed each cow all she would consume of the cheap, bulky and succulent fodders and add only a sufficient quantity of the concentrated grain feeds to keep up the milk flow and maintain the bodily weight. Each cow was weighed on Monday morning of each week throughout the year and the amount of water drank was determined by weighing the amount taken by each cow one day of every week during the winter, and by weighing the total amount of water drank by the entire herd for one day of every week during summer, that is to say, the water for each cow was weighed to her individually during winter, while in summer it was weighed collectively as a herd and calculated therefrom.

As the cows were confined to the barns every day during the summer the windows were darkened with heavy building paper which served to protect them from the excessive worry of the flies that were especially annoying during the past season.

Milking and sampling.—The milking was begun promptly at 4:30 A. M. and P. M. during the entire year, each man milking the same cows and in the same order at every milking. As soon as the milk was drawn from each cow it was carefully weighed, the weight recorded on a blank sheet, ruled for the purpose, and a sample of the milk taken each time for a determination of the butter fat content. These samples from each cow were mixed and kept in a glass jar, having a small amount of corrosive sublimate added to keep the milk from souring for a week, at the end of which time the composite sample thus obtained and kept separately from each cow, containing a sample of her milk for each of the fourteen milkings, was tested and the amount of butter fat in the milk given during the week was thus obtained.

The amounts of feed eaten and the number of pounds of milk given by each cow are recorded on daily record sheets each day and the weekly totals are entered in the large record book, sample pages of which are given herewith. It will be seen that this is ruled into fifty-two spaces, the total of which gives the yearly record.

DUCHESS.

Date.	Roughage, Lbs.				Concentrates, Lbs.				Water drank, lbs.
	Hay.	Silage.	Soiling.	Pasture.	Bran.	Oats.	Corn	Oil meal.	
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Total....	......	......	......	......	......	......	......	......	......

DUCHESS.

Date.	Live weight.	Lbs. milk.	Per cent. fat.	Lbs. fat.	Lbs. butter.	Cost of feed.	Remarks.
Total....							

TABLE I.—*Showing breed of cows, age, weight, amount of feed eaten, and cost of the same.*

Name of cow.	Breed.	Age.	Av. live weight.	Feed.									Cost of feed.
				Hay.	Silage.	Soiling.	Pasture.	Roots.	Bran.	Oats.	Corn.	Oil meal.	
			Lbs.	Lbs.	Lbs.	Lbs.	Mos.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Rose	Shorthorn	7	1,137	822	8,986	3,302	2½	1,407	1,122.3	1,122.3	285 6	457.1	$39 60
Maud	Shorthorn	6	1,105	637	9,247	4,304	2½	1.5[illegible]7	953 75	955.75	354.	304 5	36 45
Goodrich	Jersey	5	8,305	640	7,911	1,802	2½	626	836.5	874 5	460 7	435.2	32 27
Pauline	Shorthorn	6	1,263	631	9,051	3,748	2½	702	1,031.9	231.6	115.6	115.6	26 22
Dolly	Guernsey	5	1,146	627	8,[illegible]68	2,774	2½	1,721	941.	301.	150 5	150.5	26 89
Ella	Guernsey	7	9[illegible]1	600	6,374	1,802	2½	1,437	1,60[illegible].7	802.7	156.85	156.85	37 18
Chloe	Holstein	4	1,096	639	9,151	3,314	2½	1,197	1,003.9	1,006.9	458.3	391 4[illegible]	37 39
Alma	Holstein	4	911	640	8,184	4,027	2½	1,217	908.5	878.5	616.5	582.53	38 21
Murphy	Jersey	9	917	608	6,922	1,802	2½	625	1,021.4	661.4	329.6	281.1	29 15
Hoard	Jersey	5	770	622	7,707	2,230	2½	1,206	858.3	734.8	839.11	407.6	32 18
Princess	Shorthorn	2	1,058	671	7,102	2,727	4	469	668.02	465.92	255.56	232 96	27 16
Janesville Rose	Shorthorn	12	1,116	643	8,676	4,882	2½	1,262	991 25	781.25	578.6	557 2	38 19

TABLE II.— *Showing days milked during year, production of milk, butter-fat and butter, value of products and total profits.*

Name of cow.	When due to calve, 1900.	Number of days milking during the year.	PRODUCTS.					VALUE OF PRODUCTS.		Total value of products.	Total profit.
			Milk.	Fat.	Fat.	Butter.	Skim milk.	Butter.	Skim milk.		
			Lbs.	Aver per ct.	Lbs.	Lbs.	Lbs.				
Rose	June 13	365	11,131.7	4.7	500.94	584.09	10,018.	$116 81	$15 02	$131 83	$92 23
Maud	December 16	365	10,100.	4.15	425.92	484.09	9,090.	96 81	13 63	110 44	74 00
Goodrich	November 12	347	7,473.	5.3	369 58	441.89	6,725.	88 39	10 08	98 47	66 20
Pauline	November 14	365	7,996.7	4.1	32[illegible].1	364.56	7,179.	72 91	10 79	83 70	57 48
Dolly	November 4	321	6,095.	5.5	324.51	378 53	5,486 5	75 70	8 22	83 92	57 03
Ella	March 5	309	6.938.1	5.3	355.36	413.4	6,[illegible]14.3	82 63	9 36	92 04	54 86
Chloe	September 17	365	8,868.9	3.8	340.45	397.5	7,982 1	79 50	11 97	91 47	54 08
Alma	September 13	365	9,561.4	3.5	346.4	383.08	8,605.3	77 61	12 90	90 51	52 30
Murphy	November 6	303	5,418.6	6.0	306.71	368.84	4,876 8	73 76	7 31	81 07	51 92
Hoard	May 21	316	5,735.3	5.7	326.28	368.83	5,161.8	73 76	7 74	81 50	49 32
Princess	December 6	316	6,973.2	4.2	280.41	325 94	6,275.9	65 19	9 41	74 43	47 43
Janesville Rose	October 18	338	7,833	4.0	295.84	343.44	7,049.7	68 68	10 57	79 25	41 06

The foregoing tables give a detailed summary of the records of each cow in the herd.

Table No. I gives the breed, age, average live weight for the year, as determined from the weekly weighings, the total amount of each kind of feed eaten and the cost of the same. Table No. II gives data as to time of calving with reference to the beginning of the year's work; the number of days in milk; the total pounds of milk and butter fat produced, with an estimated yield of butter obtained by adding one-sixth of the weekly amount of butter fat to itself; the estimated amount of skim milk; the value of the products; and the total profit as determined by difference between cost of feed and total value of products.

Value of feeds and products.—The schedule of prices charged for each of the feeds fed and of the skim milk and butter produced is the same as that given in last year's report. (16th Ann. Rept., pp. 70–71.)

Schedule of prices fixed on feeds and products.

Hay	$6.00 per ton.
Silage	2 00 per ton.
Soiling crops	1.00 per ton.
Pasture	1.00 per month.
Roots	3.00 per ton.
Bran	12.00 per ton.
Oats	25 cts. per bu. or $15.50 per ton.
Corn	28 cts. per bu. or $9.32 per ton.
Oil meal	$22.00 per ton.
Skim milk	15 cents per 100 lbs.
Butter	20 cents per pound.

It will be seen that the price charged for some of the feeds is somewhat below the ruling market price of these products for the present season. At the same time the price put upon the butter is much below the average market quotations for this product for the year. For the sake of comparison we desire to keep the price upon all these articles constant from year to year, and we consider the prices used a fair average for Wisconsin for a period of years.

Particular attention is called to the record of the grade Guernsey cow, Dolly. It will be remembered that in last year's report (p. 88) she was credited with but 110.90 pounds of butter and

1,925.5 pounds of milk for the year, with a profit over cost of feed of 7 cents, her butter being produced at an average cost of 24 cents per pound for the feed consumed. Her present yearly record, as will be seen from the table above, gives her credit for 6,092 pounds of milk and 324.51 pounds of butter fat, or its equivalent, 378.53 pounds of butter. Comparing this record with that of last year we find an increase of 4,343.5 pounds of milk and 267.63 pounds of butter.

The following interesting observations are given of the weekly records of this cow for the weeks immediately succeeding the dropping of her calf the present year:

Record of Grade Guernsey cow Dolly.

	Av. live weight.	Lbs. milk.	Per cent. fat.	Lbs. fat.	Lbs. butter.
Yearly record, 1899	1,149	952.5	5.0	95.06	110.9
1st period, 8 weeks	1,190	1,666.7	6.1	101.66	118.3
2d period, 8 weeks	1,027	1,410.9	5.1	67.30	79.28
3d period, 8 weeks	1,063	1,050.6	4.8	50.01	58.55
Best week, 1st period	....	251.0	6.3	15.86	18.5
Best week, 2d period	....	175.3	5.8	10.23	11.93
Best week, 3d period	....	130 7	5.2	6.84	7 98
Yearly record, 1900	1,146	6,095.	5.5	324.51	378.53

Food eaten.

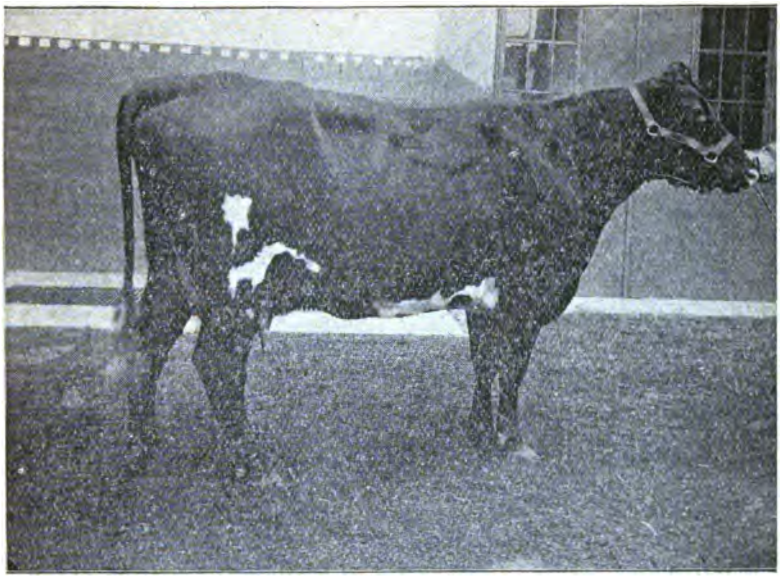
	Hay.	Silage.	Bran.	Oats.	Corn.	Oil meal.	Roots.
1st period, 8 weeks	112	1,780	280	....	....	....	1,731
2d period, 8 weeks	224	2,286	98	98	49	49	....
3d period, 8 weeks	224	2,436	112	112	56	56	....
Best week, 1st period	21	200	42	....	....	....	280
Best week, 2d period	28	327	14	14	7	7	....
Best week, 3d period	28	348	14	14	7	7	....

A study of these tables will prove interesting. It will be seen at a glance that there was a remarkable falling off in her production between the amount produced in the best week in the first period of eight weeks, and the best week in the third

period of eight weeks. The feed received indicates that she ate as much feed during the second and third periods as she did during the first. This is a remarkable instance of the folly of condemning a cow on a single day, a single week, or even a single year's record.

The case of Pauline, a beefy Grade Shorthorn cow, is another example, but the difference is not so great in the production of the two years. Her record, completed in 1899, gave her credit for 4,335 pounds of milk and 184.33 pounds of butter fat, or 215.05 pounds of butter. Her present yearly record gives her credit for 7,996.7 pounds of milk and 322.1 pounds of butter fat, or 364.56 pounds of butter. Here we have a difference of 3,661.7 in pounds of milk, or 149.51 in pounds of butter. In her record of the present year the profit over cost of feed was $57.48, while last year it was but $20.86.

The photographs of a number of these cows are reproduced in the following pages, with a short sketch of the breeding and performance of each given beneath the photograph.



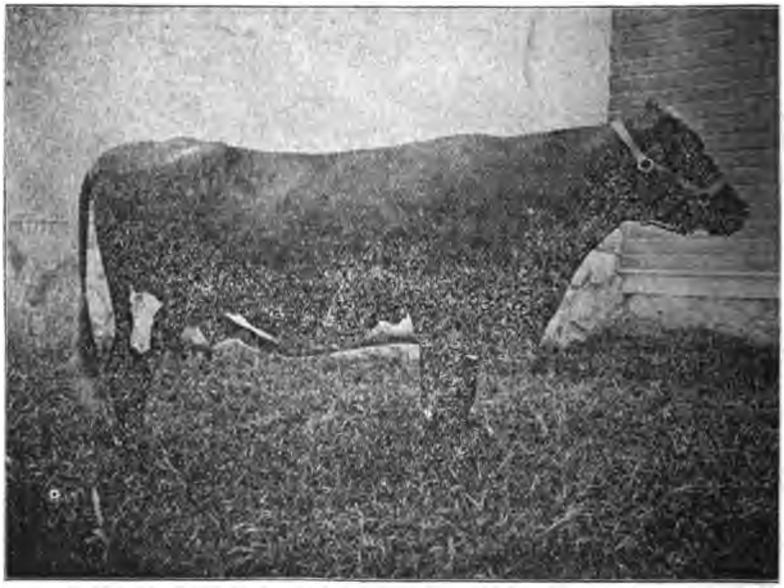
ROSE. GRADE SHORTHORN.

Description and History.—For description of this cow see 16th Annual Report, page 75. We give herewith a brief outline of her breeding, which has been traced since last report was issued:

She was sired by the pure-bred Shorthorn bull General Bly of Oakland 17th 107,946. The dam of this bull was Oxford Bloom 7th of Oakland, a cow that won first prize in her class some years ago with strong competition at the Minnesota State Fair and at the Wisconsin State Fair two years in succession when shown as a Shorthorn cow by her breeders, Kiser Bros. The sire of Rose's dam was the pure-bred Shorthorn bull Sharon Duke 9th 89,384, and is represented as being a very typical Shorthorn bull, his sire being Sharon Duke of Geneva 64,454, and his dam 7th Profitable of Oakland. Rose's grandam was sired by a pure-bred Shorthorn bull bred by Wm. Kiser, and her great grandam was sired by a pure-bred Shorthorn bull bred by Wm. Lysaght, Dane Co., Wis. The fourth dam of Rose was a common scrub or native cow with no pretensions to a high type of dairy form or performance.

Production.—During her past period of lactation, which lasted 365 days, she gave 11,131.7 lbs. of milk, containing 500 lbs. of butter fat or its equivalent of 584.09 lbs. of butter. The average percentage of fat in her milk for the period was 4.7 per cent.

Profit.—The total feed consumed during the year cost $39.60. The total value of butter and skim milk when estimated at prices given on preceding pages was $131.83, leaving a profit over cost of feed of $92.23. Her butter produced at a cost of 6.7 per pound is cheaper than that of any cow in the University dairy herd.

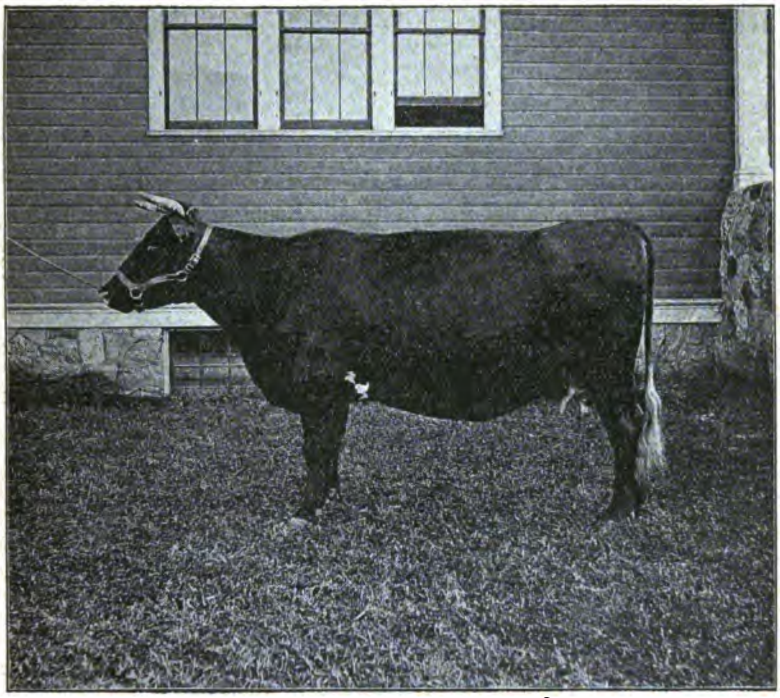


MAUD. GRADE SHORTHORN.

Description and History.—A description of this cow was also given in the 18th Annual Report, page 86. Maud and Rose are sired by the same bull, General Bly of Oakland 17th, but Maud was out of same cow as Rose's dam so that these two cows are bred in every way similar except that Rose had one more cross of a Shorthorn sire. The grandam of Rose and dam of Maud was "Old Bob," a cow described as being very similar in every way to Maud. She was sold at 16 years of age, after milking two years in succession without calf.

Production.— Maud milked 365 days during her period of lactation during which time she gave 10,100 lbs. of milk and 426.67 lbs. of fat, or 484.09 lbs. of butter. The average percentage of fat in her milk for the entire year was 4.15 per cent.

Profit.—The total feed consumed for the year was valued at $36.44. The total value of products was $110.44, giving a profit over cost of feed of $74.00. Her milk was produced at a cost of 36 cents per cwt., and the butter at 7.5 cents per pound.

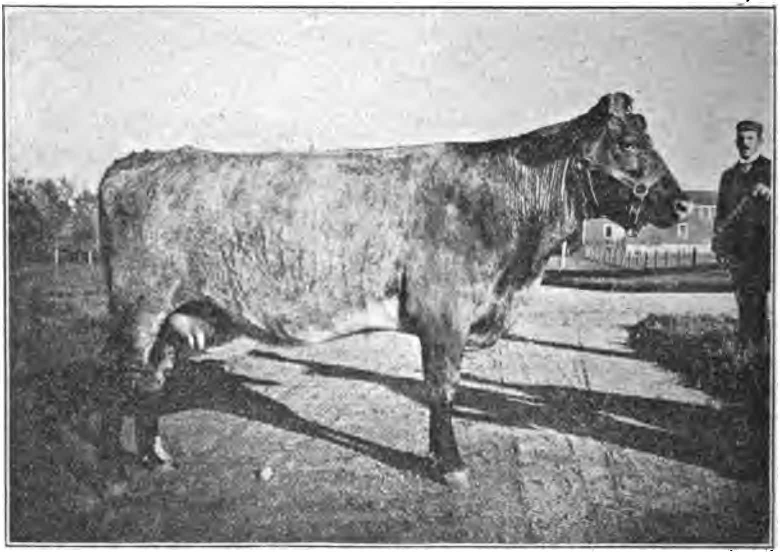


JANESVILLE ROSE. SHORTHORN.

Description and History.—The above photograph represents a pure bred Shorthorn cow 12 years old, bred by Walter Little, Janesville, Wis. She was purchased from him a few weeks before dropping her calf and during the first part of the year she gave every evidence of being very homesick, which in all probability was responsible for her record not being much higher. As will be seen from the photograph, she represents a good type of the up to date Shorthorn breeding cow. She traces directly to imported stock and is the dam and grandam of many choice cows and heifers owned by Mr. Little.

Production.—During a milking period of 338 days she gave 7,833 lbs. of milk which contained 295.84 lbs. of fat or 343.44 lbs. of butter. The average amount of butter fat in her milk for the year was 4.0 per cent.

Profit.—Her feed for the year cost $38.19 cents, being the second largest feed account in the herd, which is no doubt attributable to the poor condition of her teeth at twelve years of age. Her butter and skim milk products were valued at $79.25, leaving a profit of $41.06.



PRINCESS. GRADE SHORTHORN.

Description and History.—The above photograph represents a high grade Scotch bred Shorthorn heifer after completing a year's record at two years of age. This heifer was purchased from N. P. Clarke, of St. Cloud, Minn., with a car load of steers at a cost of $3.75 per cwt. She dropped a calf on December 10, 1899, and gave milk for 316 days, or until within 43 days of her next parturition. As will be seen from her photograph, she is very thick and blocky and shows very little refinement except about the head. Her udder is very small at all times, but very symmetrical. It is a constant wonder when milking her how so much milk is secreted by so small a vessel.

Production.—She gave in 316 days of a milking period with her first calf dropped when she was two years old 6,973.2 lbs. of milk which contained 280.41 lbs. of fat or 325.94 lbs. of butter. Her milk tested an average 4.2 per cent. fat for the year.

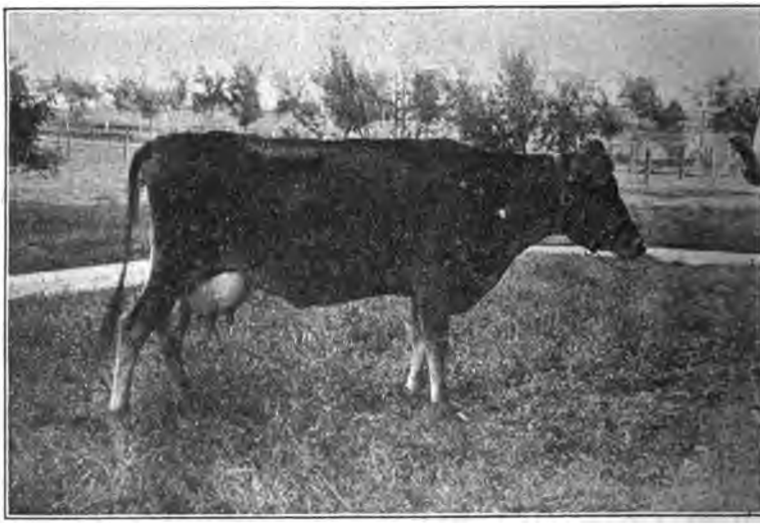
Profit.—She consumed $27.16 worth of feed during the year and her products were valued at $74.43, leaving a profit of $47.27. Her milk was produced at a cost of 39.1 cents per 100 lbs. and her butter at a cost of 8.3 cents per pound.

PAULINE. GRADE SHORTHORN.

Description and History.—A description of this cow was given on page 87 of last year's report. During that year she was one of the poorest producers of any cow in the herd, and was considered by many expert judges as being of no value as a dairy cow.

Production.—She produced 7,996.7 lbs. of milk during the year and 322.1 lbs. of butter fat, or 364.56 lbs. of butter. The average amount of butter fat in her milk was 4.1 per cent.

Profit.—Her feed for the year cost $26.22 and the products were valued at $83.70, leaving a profit over cost of feed of $57.48, as compared with a profit oi $20.86 last year. Her butter was produced at a cost of 7.19 cents per lb., and her milk at 32.7 cents per 100 lbs., this being the cheapest milk production of any cow in the herd, which is very surprising when it is remembered that she is one of the heaviest and most beefy cows in the barn.



HOARD. GRADE JERSEY.

Description and History.—The above photograph represents a grade Jersey cow with two crosses of pure Jersey breeding. She was selected for the Station by Ex-Governor W. D. Hoard, of Fort Atkinson, and is a very typical special purpose dairy cow. Her average weight for the year as a four-year-old was 770 lbs. We have invariably found that a dairy cow will not do herself justice the first year after leaving her home to locate in new quarters and we have every reason to believe that this cow will give a much better account of herself in succeeding years than she has the past year.

Production.—She gave during the year 5,735.3 lbs. of milk containing 326.28 lbs. of fat, or 368.83 lbs. of butter. The average amount of butter fat in the milk was 5.7 per cent., only one cow in the herd giving richer milk.

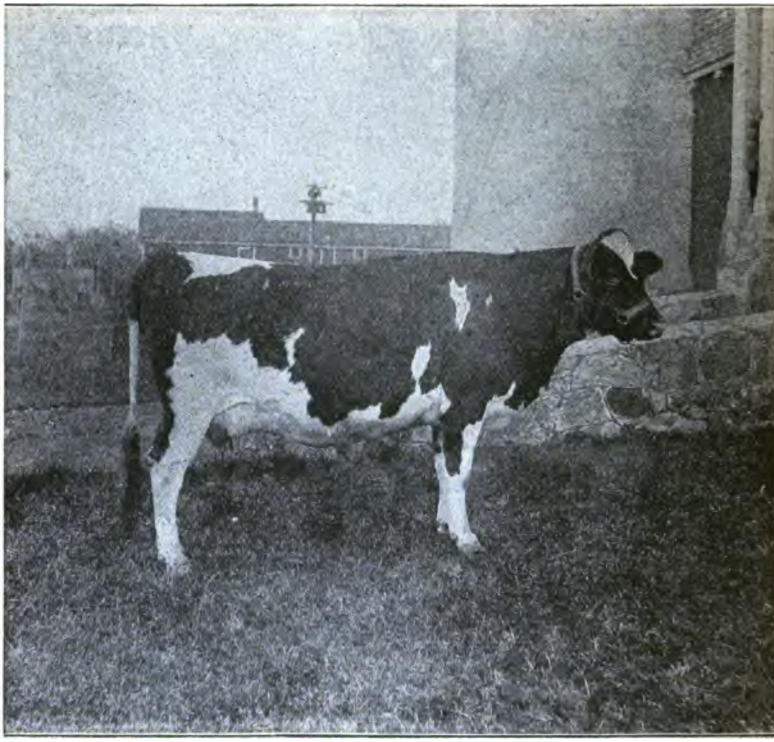
Profit.—Her feed for the year cost $32.18, and her butter and skim milk products were valued at $81.50, leaving a profit of $49.32. Her milk was produced at a cost of 56.1 cents per 100 pounds, and the butter at 8.7 cents per pound.

GOODRICH. GRADE JERSEY.

History and Description.—A description and photograph is also given of this cow in the 16th Annual Report. As stated therein we expected her to excel her record of last year and we were not disappointed.

Production.—She gave during the year 7,473 lbs. of milk, containing 369.58 lbs. of butter fat, or 441.89 lbs. of butter. The average percentage of butter fat in her milk for the year being 5.3 per cent.

Profit.—She consumed during the year $32.27 worth of feed, and her products were valued at $98,47, leaving a profit of $66.20. Her butter was produced at a cost of 7.36 cents per pound, and her milk at a cost of 43.1 cents per 100 lbs.

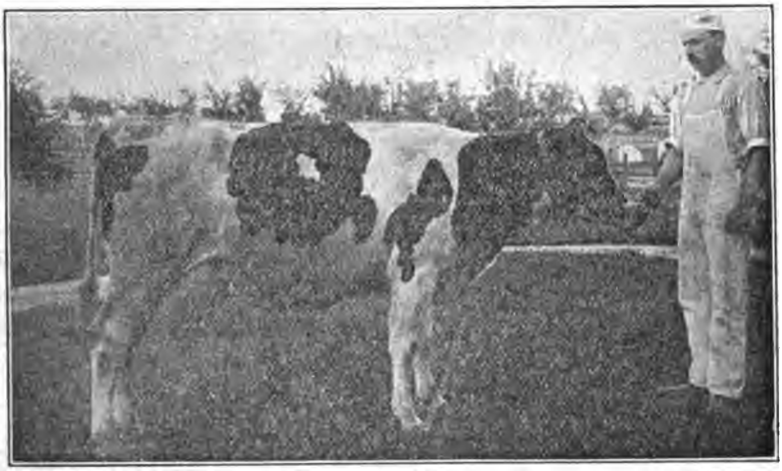


DOLLY. GRADE GUERNSEY.

History and Description.—A description of this cow also appears in the 16th Annual Report, where she is described as being somewhat of a beefy type. Last year she produced only 1,952.5 lbs. of milk containing 95.06 lbs. of butter fat. A comparison of her record of last year with the present year is given on page 323.

Production.—She gave during the present year 6,095 lbs. of milk containing 324.51 lbs. of fat, and 378.53 lbs. of butter. The average butter fat test of her milk for the year was 5.5 per cent.

Profit.—The feed she ate was valued at $26.89, the lowest in feed cost of any cow but Pauline. Her skim milk and butter products were valued at $83.92, leaving a profit over cost of feed of $57.03. Her butter cost 7.1 cents and her milk was produced at a cost of 44.1 cents per 100 lbs.

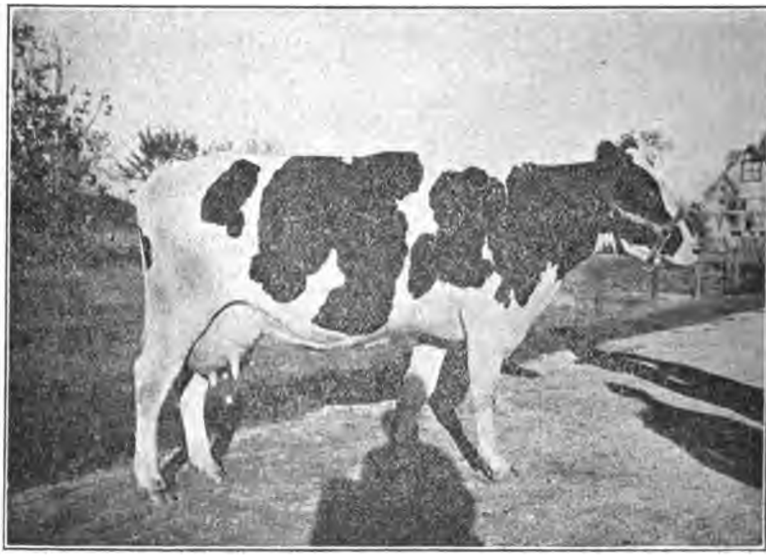


ALMA. HOLSTEIN FRIESIAN.

Description and History.—This is a small and very much refined pure-bred Holstein cow, her average weight for the year being 911 lbs. She was on experiment for the greater part of the year so that we are justfied in saying that she is capable of doing much better in the future. As will be seen from the above photograph, she is quite defective in her front udder, but is a very perfect dairy cow in all other respects.

Production.—During the year she gave 9,561.4 lbs. of milk containing 346.4 lbs. of butter fat, or 388.08 lbs. of butter. The amount of butter fat in the milk for the year averaged 3.5 per cent.

Profit.—She ate feed to the value of $38.21, and her products were valued at $90.51, leaving a profit on cost of feed of $52.30. Her butter was produced at a cost of 9.8 cents per pound and her milk at a cost of 39 cents per 100 lbs.



CHLOE. HOLSTEIN FRIESIAN.

Description and History.—This is a pure-bred cow of rich breeding. This record was made in her three-year-old form at her second parturition. As will be seen from the above photograph, she is a large, strong cow, a good feeder and a very persistent milker. She has not a perfect udder as will be noticed, but it is of very fine quality. During the year she increased in size and we expect a better record the coming year as she has now reached maturity.

Production.—She gave during the year 8,868.9 lbs. of milk, which contained 340.45 lbs. of fat, or 397.5 lbs. of butter. The butter fat test of her milk for the year was 3.8 per cent., which is a good average test for a Holstein cow.

Profit.—She ate feed to the value of $37.39 during the year and her products were valued at $91.47, leaving a profit of $54.08. The food cost of 100 lbs. of milk was 42.1 cents, and of one pound of butter, 8.99 cents.

The foregoing records, when taken in connection with those reported last year, certainly contain some surprising results in favor of the grade Shorthorns as profitable milkers. The cows of this breed here reported have been bought from four different herds in widely separated parts of the country, and have been bred from a variety of lines of breeding. The pure-bred cow, Janesville Champion Rose 58th, registered in Vol. 14, page 678 of A. S. H. B., shows the wonderful milking power and vitality of this class. Her record is one that any Jersey, Guernsey, or Holstein cow might be proud of at twelve years of age.

The Grade Shorthorn heifer, Princess, with two top crosses of Scotch bred beefing bulls in her pedigree, has shown a record as a two-year old that very few pure-bred special purpose dairy animals can be expected to excel.

THE WISCONSIN FERTILIZER LAW.

[Sections 1494c, 1494d and 1494e, Wisconsin Statutes of 1898.]

SECTION 1494c. Every person who shall, in this state, sell or expose for sale any commercial fertilizer or any material used for fertilizing purposes, the price of which exceeds ten dollars per ton, shall affix to every package of such fertilizer or material, in a conspicuous place on the outside thereof, a plainly printed statement clearly and truly certifying the number of net pounds therein, name or trade-mark under which the article is sold, name of the manufacturer or shipper, place of manufacture, place of business of the manufacturer and of the following fertilizing constituents, namely: The percentage of nitrogen in an available form, of potash soluble in water and of available phosphoric acid, soluble and reverted, as well as total phosphoric acid. Every such person shall also file with the director of the agricultural experiment station of the university of Wisconsin, in the month of December in each year, a certified copy of such statement for every such fertilizer or material bearing a distinguishing brand or trademark and which he sells or exposes for sale, which copy shall, when required by such director, be accompanied by a sealed glass jar or bottle containing at least one pound of such fertilizer or material, and an affidavit that such sample corresponds, within reasonable limits, to the fertilizer or material which it represents in the percentage of the aforesaid constituents, which affidavit shall apply to the remaining portion of the then calendar year. Additional brands of such fertilizer or material may be offered for sale during the year, provided samples and affidavits are so filed at least one month before they are offered, in which case an analysis fee of double the usual amount must be paid. A deposit of the sample of fertilizer shall be required by said director unless the person selling or offering for sale a fertilizer or material within this section shall certify that its composition for the succeeding year is to be the same as given in the last previously certified statement, in which case the furnishing of a sample shall be at the discretion of said director.

SECTION 1494d. Said director shall analyze or cause to be analyzed all such samples and publish the results of such analysis in a bulletin or report on or before the first day of the next succeeding April. Every manufacturer, importer, agent or seller of any such fertilizer or material shall pay annually to said director for each brand thereof sold within this state the sum of twenty-five dollars, and upon doing so and complying with the other provisions of law shall receive from him a certificate of such compliance which shall be a license for the sale of each brand thereof within the state for the calendar year for which such fee is paid. All moneys received by said director pursuant to this section shall be paid into the treasury of said station. Any person who shall sell or expose for sale any commercial fertilizer or material used for fertilizing purposes which is within the provisions of the preceding section without complying with the foregoing provisions or which contains a substantially smaller percentage of fertilizing constituents than are indicated by the printed statement thereon shall be punished by a fine of one hundred dollars for the first offense and of two hundred dollars for each subsequent offense.

SECTION 1494e. Said director shall annually analyze or cause to be analyzed at least one sample of every fertilizer or material used for fertilizing purposes sold or exposed for sale under the two preceding sections and enforce their provisions by prosecuting or causing the prosecution of every person who shall violate them. He may in person or by deputy, on tendering the value thereof, take a sample, not exceeding two pounds, for said analysis from any lot or package of fertilizer or any material used for fertilizing

purposes which may be in the possession of any manufacturer, importer, agent or dealer in this state; said sample shall be drawn in the presence of the person from whom taken or his representative, be taken from a parcel or a number of packages which shall not be less than ten per centum of the whole lot sampled, be thoroughly mixed and divided into two equal samples, placed in glass vessels and carefully sealed and a label placed on each, stating the name or brand of the fertilizer or material sampled, the name of the party from whose stock the sample was drawn, the time and place of such taking; said label shall be signed by the director or his deputy and such person or his representative at the drawing and sealing of said samples; one of said duplicate samples shall be retained by the director and the other by the party whose stock was sampled; the sample retained by the director shall be for comparison with the certified statement named in section 1494c. The result of the analysis of the sample or samples so procured shall be reported to the person requesting the analysis and be published in a report or bulletin to be issued within a reasonable time.

EXCHANGES.

The Station takes pride in the fact that it has on file an almost complete list of the leading agricultural papers in the United States, besides many from foreign countries, and some not strictly treating of agriculture. These papers come to the Station in exchange for its reports and bulletins. While of the highest value to those connected with the Station as the expression of agricultural experience and sentiment, they are placed where they can be read and referred to by our agricultural students, and others of the University, as well as by visitors. Any one desiring sample copies of these papers can as a rule secure them upon application to the publishers, at the addresses given.

FOREIGN EXCHANGES.

Agricultural Gazette, London, England.

Agricultural Journal, Cape Town, South Africa.

Analyst, London, England.

Australian Irormonger, Melbourne, S. Australia.

Bulletin des Seances de la Societe Nationale d' Agriculture de France, Paris, France.

Chronique Agricole du Canton du Vaud, Lausanne, Switzerland.

Co-operative Farmer and Maritime Dairyman, Sussex, N. B.

Extrait des Travaux de la Soc. Centr. d'Agr. de la Seine Inf., Rouen, France.

Farmer's Advocate, London, Ontario.

Farming, Toronto, Canada.

Farm and Dairy, Sydney, N. S. W.

Field, London, England.

Irish Farming World, Dublin, Ireland.

Journal für Landwirtschaft, Berlin, Germany.

Journal of the Bath and West of England Society, Bath, Eng.

Journal of the British Dairy Farmers' Ass'n, London, England.

Journal of the Council of Agriculture, Hobart, Tasmania.

Journal of Royal Agricultural Society of England, London, England.

Kgl. Landtbruks-Akademiens Handlingar och Tidskrift, Stockholm, Sweden.

L'Agricultura Moderna, Milan, Italy.
Landbouwgalm, Kortrijk, Belgium.
Landwirtschaftliche Wochenblatt f. Schlesw.-Holtstein, Kiel, Germany.
Landwirtschaftliche Wochenschrift, Berlin, Germany.
Le Messager Agricole, Montpelier, France.
L'Industrie Laitiere, Paris, France.
Live Stock Journal, London, England.
Milch Zeitung, Bremen, Germany.
Mittheilungen des Milchw. Vereins im Allgäu, Memmingen, Germany.
Neue Zeitschrift für Rübenzucker Industrie, Berlin, Germany.
North British Agriculturist, Edinburgh, Scotland.
North West Farmer, Winnipeg, Manitoba, Canada.
Rural World, London, England.
Scottish Farmer, Glasgow, Scotland.
Tidsskrift for det norske Landbrug, Christiania, Norway.
Tidsskrift for Landökonomi, Copenhagen, Denmark.
Ugeskrift for Landmänd, Copenhagen, Denmark.
Weekly Times, Melbourne, Australia.
Zeitschrift des Landw. Vereins in Bayern, Munich, Germany.

DOMESTIC EXCHANGES.

Acker-und Gartenbau Zeitung, Milwaukee, Wis.
Agricultural Epitomist, Indianapolis, Ind.
American Agriculturist, New York City.
American Bee Journal, Chicago, Ill.
American Cultivator, Boston, Mass.
American Fruit and Vegetable Grower, Rochester, N. Y.
American Grange Bulletin, Cincinnati, O.
American Packer, Baltimore, Md.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Swineherd, Chicago, Ill.
American Thresherman,* Madison, Wis.
Baltimore Weekly Sun, Baltimore, Md.
Beet Sugar Gazette, Chicago, Ill.
Blooded Stock on the Farm, Stock, Pa.
Boston Weekly Globe, Boston, Mass.
Breeder's Gazette, Chicago, Ill.
Bulletin of the American Devon Cattle Club, Wheeling, W, Va.
California Cultivator, Los Angeles, Cal.
Chicago Dairy Produce, Chicago, Ill.
Cold Storage, New York City.
Colman's Rural World, St. Louis, Mo.
Connecticut Farmer, Hartford, Conn.
Country Gentleman, Albany, N. Y.
Cotton Planter's Journal, Memphis, Tenn.
Creamery Gazette, Des Moines, Iowa.
Creamery Journal, Waterloo, Iowa.
Cultivator, Omaha, Neb.
Dairy Age, Beloit, Kansas.
Dairy & Creamery, Chicago, Ill.
Dairy Reporter, St. Paul, Minn.
Dairy World, Chicago, Ill.
Detroit Free Press, Detroit, Mich.
Dixie Miller, Nashville, Tenn.
Dorset Courier, Washington, Pa.

*Received in Horticultural and Experiment Station libraries.

Drainage and Farm Journal, Indianapolis, Ind.
Elgin Dairy Report, Elgin, Ill.
Fanciers' Review, Chatham, N. Y.
Farm and Fireside, Springfield, Ohio.
Farm and Home, Springfield, Mass.
Farm Home, Springfield, Ill.
Farm Magazine, Knoxville, Tenn.
Farm Magazine, Milwaukee, Wis.
Farm News, Sprinfield, Ohio.
Farm Students' Review, St. Anthony Park, Minn.
Farmer, The, St. Paul, Minn.
Farmer and Breeder, Springfield, Ill.
Farmers' Guide, Huntington, Ind.
Farmers' Home, Dayton, Ohio.
Farmers' Home Journal, Louisville, Ky.
Farmers' Magazine, Madison, Wis.
Farmers' Review,* Chicago, Ill.
Farmers' Union, Chicago, Ill.
Farmers' Voice,* Chicago, Ill.
Farm, Field and Fireside, Chicago, Ill.
Farm Journal, Philadelphia, Pa.
Farm, Stock and Home, Minneapolis, Minn.
Field and Farm, Denver, Colo.
Florist's Exchange,* New York City.
Forester, Princeton, N. J.
Fruitman, Mount Vernon, Iowa.
Geflügel Züchter, Wausau, Wis.
Golden Egg, St. Louis, Mo.
Grange Visitor, Charlotte, Mich.
Green's Fruit Grower,* Rochester, N. Y.
Hoard's Dairyman, Ft. Atkinson, Wis.
Holstein-Friesian Register, Battleboro, Vt.
Home and Farm, Louisville, Ky.
Horticultural Gleaner, Austin, Tex.
Horticultural Visitor,* Chicago. Ill.
Hospodar, Omaha, Neb.
Indiana Farmer, Indianapolis, Ind.
Iowa Homestead, Des Moines, Ia.
Irrigation Age, Chicago, Ill.
Jersey Bulletin, Indianapolis, Ind.
Kansas Farmer, Topeka, Kas.
Live Stock Indicator, Kansas City, Mo.
Live Stock Report, Chicago, Ill.
Louisiana Planter, New Orleans, La.
Market Basket, Philadelphia, Pa.
Market Gardener, Minneapolis, Minn.
Michigan Farmer, Grand Rapids, Mich.
Midland Poultry Journal, Kansas City, Mo.
Minnesota Horticulturist,* Minneapolis, Minn.
Mirror and Farmer, Manchester, N. H.
Moulton's Monthly, New York City.
National Stockman, Pittsburgh, Pa.
Nebraska Farmer, Lincoln, Neb.
New England Farmer, Boston, Mass.
New England Florist, Boston, Mass.
New England Homestead, Springfield, Mass.
New York Produce Review and American Creamery, New York City.
North Pacific Rural Spirit, Portland, Oregon.
Northwestern Agriculturist, Minneapolis, Minn.
Northwestern Horticulturist, Monroe, Mich.
Northwestern Horticulturist, Tacoma and Seattle, Washington.
Northwest Weather and Crops, Minneapolis, Minn.
Ohio Farmer, Cleveland, Ohio.
Orange Judd Farmer,* Chicago, Ill.
Oregon Agriculturist, Portland, Ore.
Pacific Rural Press, San Franciso, Cal.
Pharmaceutical Review, Milwaukee, Wis.
Poultry Monthly, Albany, N. Y.

* Received in Horticultural and Experiment Station libraries.

Practical Dairyman, Indianapolis, Ind.
Practical Dairyman and Agriculturist, Chatham, N. Y.
Practical Farmer, Philadelphia, Pa.
Prairie Farmer, Chicago, Ill.
Public Ledger, Philadelphia, Pa.
Ranch and Range, Seattle, Washington.
Rural Californian, Los Angeles, Cal.
Rural New-Yorker,* New York City.
Rural Spirit, Portland, Oregon.
Ruralist,* Gluckheim, Md.
Weekly Call, San Francisco, Cal.
Southern Cultivator, Atlanta, Ga.
Southern Farmer, New Orleans, La.
Southern Farm Magazine, Baltimore, Md.
Southern Live Stock Journal, Starkville, Miss.
Southern Planter, Richmond, Va.
Southern States, Baltimore, Md.
Southwest, Springfield, Mo.
Strawberry Culturist,* Salisbury, Md.
Strawbery Specialist,* Kitrell, N. C.
Successful Farmer, Sioux Falls, S. D.
Sugar Beet, Philadelphia, Pa.
Tobacco Leaf, New York City.
Wallace's Farmer, Des Moines, Ia.
Western Agriculturist and Live Stock Journal, Chicago, Ill.
Western Creamery, San Francisco, Cal.
Western Fruit Grower, St. Joseph, Mo.
Western Rural, Chicago, Ill.
Western Stockman and Cultivator, Omaha, Neb.
Western Swineherd, Genesee, Ill.
Whitney's Swine Advocate, Logansport, Ind.
Wisconsin Agriculturist,* Racine, Wis.
Wisconsin Farmer,* Madison, Wis.
Wisconsin Horticulturist,* Baraboo, Wis.
Wool and Sheep Markets, Chicago, Ill.

STATE PAPERS.

The Record, Algoma, Wis.
Amherst Advocate, Amherst, Wis.
Antigo Journal, Antigo, Wis.
Langlade County Special, Antigo, Wis.
Weekly News Item, Antigo, Wis.
The Eagle, Augusta, Wis.
The Times, Augusta, Wis.
Balsam Lake Ledger, Balsam Lake, Wis.
The Courant, Berlin, Wis.
Jackson County Journal, Black River Falls, Wis.
Bloomington Record, Bloomington, Wis.
Brillion News, Brillion, Wis.
Independent, Brodhead, Wis.
Register, Brodhead, Wis.
Rock County Banner, Clinton, Wis.
Advocate, Cumberland, Wis.
The Wisconsin Leader, Merrillan, Wis.
Winnebago Anzieger, Menasha, Wis.
The Republican, Necedah, Wis.
Press, New London, Wis.
Republican, New London, Wis.
St. Croix Republican, New Richmond, Wis.
The Voice, New Richmond, Wis.
Republican, Oconomowoc, Wis.
La Crosse County Record, Onalaska, Wis.
Observer, Oregon, Wis.
Enterprise, Palmyra, Wis.
Grant County Wittness, Platteville, Wis.
Press, Poynette, Wis.
Free Press, Reedsburg, Wis.
The Times, Reedsburg, Wis.
Rib Lake Herald, Rib Lake, Wis.

* Received in Horticultural and Experiment Station libraries.

Enterprise, Doerfield, Wis.
Chronicle, Dodgeville, Wis.
Sun, Dodgeville Wis.
The Leader, Eau Claire, Wis.
The Telegram, Eau Claire, Wis.
The Times Review, Fennimore, Wis.
The Journal, Grantsburg, Wis.
The News, Hammond, Wis.
Weekly Press, Highland, Wis.
The Sentry, Hillsboro, Wis.
The Independent, Juneau, Wis.
The Republican & Leader, La Crosse, Wis.
Reporter, Lancaster, Wis.
Weekly Teller, Lancaster, Wis.
The Herald, Lake Geneva, Wis.
Lodi Valley News, Lodi, Wis.
Tribune, Manitowoc, Wis.
The Eagle, Marinette, Wis.
The Medford Democrat, Medford, Wis.
Lincoln County Anzieger, Merrill, Wis.
The Chronotype, Rice Lake, Wis.
The Advance Press, Ripon, Wis.
The Telegram, Sheboygan, Wis.
Sheboygan County News, Sheboygan Falls, Wis.
Watchman, Shell Lake, Wis.
News, Shiocton, Wis.
Republican, Stanley, Wis.
St. Croix Valley Standard, St. Croix, Wis.
Door County Advocate, Sturgeon Bay, Wis.
Door County Democrat, Sturgeon Bay, Wis.
The Tomahawk, Tomahawk, Wis.
Journal, Tomah, Wis.
Herald, Trempealeau, Wis.
The Post, Waupaca, Wis.
Waupun Leader, Waupun, Wis.
Wonewoc Reporter, Wonewoc, Wis.

ACKNOWLEDGMENTS.

From U. S. Department of Agriculture, Washington, D. C. (1,000 lbs.) Sugar beet seed (five varieties).

From Propaganda of Nitrate of Soda, New York City. 300 lbs. Nitrate of Soda.

From Armour Fertilizer Works, Chicago, Ill. One bag each (100 lbs.) of Bone Meal, Acidulated Bone Meal, and Superphosphate.

From German Kali Works, New York City. One bag each of Sulphate of Potash and Muriate of Potash (200 lbs. each).

From S. Hoxie, Supt. Advanced Registry, Yorkville, N. Y. One cattle measure.

From W. P. Kennard, Waukegan, Wis. Ten samples of glucose factory products.

From Dr. Theobald Smith, Boston, Mass. One culture of B. tuberculosis.

From M. P. Ravenel, M. D., Philadelphia, Pa. Five cultures of B. tuberculosis.

From American Steel & Wire Fence Co., Chicago, Ill. Four Razor Back Pigs.

From A. A. Arnold, Galesville, Wis. One Shorthorn cow.

From Cole Bros., Spring Grove, Ill. One Rambouillet ram.

From S. Hoxie, Yorkville, N. Y. One Measuring apparatus for stock.

From Cornish, Curtis & Green Mfg. Co., Ft. Atkinson, Wis. One Curtis milk heater, one Kasper curd mill, one turbine Babcock tester.

From Wagner Glass Works, New York. One-half dozen Wagner double bore skim milk test bottles, one-fourth dozen Wagner's "up-to-date" pipettes, one combined acid bottle and measures.

From F. B. Fargo Mfg. Co., Lake Mills, Wis. One dividend statement book, one consignment register book, one No. 1 Baby Victor churn, one Victor Babcock milk tester.

From C. W. Putnam & Sons, Aurora, Ill. Seventy-five patrons' account books.

From Chr. Hansen's Laboratory, Little Falls, New York. Three packages Lactic Ferment.

From O. Douglass Butter Culture Co., Boston, Mass. One bottle butter culture.

From The Heller & Merz Co., New York, N. Y. One gallon butter color.

From DeLaval Separator Co., Chicago, Ill. Four rope belts for Alpha separator.

From F. A. Tripp, Chicago, Ill. Three barrels Genesee butter salt.

From S. C. Keith, Jr., Charlestown, Mass. Ten bottles butter culture.

From E. Sudendorf, Elgin, Ill. One pint Wells Richardson butter color.

From J. S. McGowan, Janesville, Wis. Four plum trees.

From J. I. Lord, Pompanoosuc, Vt. Twelve packages of cions.

From Armour & Co.'s Elevator, through Geo. F. Stone, Sec'y of Chicago Board of Trade, Chicago, Ill. Eight bags of grain, one bushel each.

From Bartlett, Frazer & Co., through Geo. F. Stone, Sec'y of Chicago Board of Trade, Chicago, Ill. Six bags of grain, one bushel each.

From Albert Dickinson Co., Chicago, Ill. Twenty pounds of clover seed.

From D. W. C. Priest, Fond du Lac, Wis. Cions of a native American plum and of Blood's Golden plum.

From W. H. Owen, Catawba Island, Ohio. One pail U. S. Standard caustic potash Whale Oil Soap.

From U. S. Dept. of Agriculture, Washington, D. C., Division of Botany. Quantity of tubers of Stachys Sieboldi.

From William Tool, Baraboo, Wis. One package pansy seed; basket of double petunia plants.

From A. J. Philips, West Salem, Wis. Sprout from original Wealthy apple tree.

From J. F. Wagner, Bennett, Iowa. Package plum cions.

From W. Atlee Burpee & Co., New York. Twenty-six packages flower and vegetable seeds.

From H. A. Stoothoff & Co., New York, N. Y. One package "Aphia" brand Tobacco Whale Oil Soap.

From F. Bartelder & Co., Lawrence, Kansas. One package Kansas Standard Tomato; one package Parpalum dilitatum.

From J. Luchsinger, Monroe, Wis. Package cions of seedling apples.

From E. H. Dartt, Owatonna, Minn. Package of apple cions.

From H. A. Robinson, Foxcroft, Maine. Package of apple cions.

From Scabcura Dip Co., Chicago, Ill. One package Nikoteen "Aphis."

From Arthur & Hillis Bros, McFall, Mo. One Insect Exterminator.

From Benjamin Rastall, Viola, Wis. Package apple and pear cions; two trees each of John's No. 1 and 5 apple.

From Stark Bros. Nursery and Orchards Co., Louisiana, Mo. Package cions of apples,

From Geo. J. Kellogg, Janesville, Wis. Package of cions of "Vic" apple.

From H. A. Terry, Crescent, Iowa. Package of cions of Marcellas, Van Houten and Nellie plums.

From J. S. Hewett, Waupun, Wis. Three trees each of Chandler and Gam apples.

From W. J. Moyle, Little Silver, N. J. Twelve geranium and thirteen canna plants.

From the Ontario Agricultural College, Guelph, Canada. Two quarts each of the following seed peas: Oddfellow, Early Britain, White Wonder, Prussian Blue, and the same amount of Herison Bearded Spring wheat and Wild Goose Spring wheat.

From J. H. McNown, Mauston, Wis. Two quarts each of Alsike and Mammoth clover.

From the Iowa Agricultural Experiment Station, Ames, Iowa. One-half pound package each of Black Russian, Early Dawson, Nebraska Gold Mine, White Belgian, Silver Mine, Early Champion, Henderson's, Clydesdale and Red Rust Proof seed oats.

From the Minnesota Agricultural Experiment Station, St, Anthony Park, Minn. One pound package each of Minnesota Numbers 51, 66, 146, 149, 157, 163, 165, 169, 171, 181, 185, and 188 Spring wheat; one peck sack each of Minnesota Numbers 6, 23, 26, 29, 32, 35, 77, 85, 194 and 196 seed oats; one-half peck package each of Minnesota Numbers 6, 15, 28, 100 and 105 seed barley; one-half peck package each of Minnesota Numbers 2, 35 and 36 fall and spring rye.

From the U. S. Department of Agriculture, Division of Botany, Washington, D. C. Sixty-one packages and sacks of various kinds of seed grain.

From McCormick Harvesting Machine Co., Madison, Wis. The use of a Corn Harvester during harvest.

From Arch. McNeilage, Secy., Glasgow, Scotland. Clydesdale Stud Book, Vol. 22, 1900.

From Alex Galbraith, Secy., Janesville, Wis. American Clydesdale Stud Book, Vols. 8 (1894), 9 (1900).

From Frank B. Hearne, Secy., Independence, Mo. American Galloway Herd Book, Vols. 1, 2, 3, 5, 6, 7, 8, 9, 10.

From Rev. John Gillespie, LL. D., Manswals Manse, Dumfriesshire, Eng. Galloway Herd Book, Vol. 20, 1900.

From W. H. Caldwell, Peterboro, N. H. Guernsey Breeders' Assn. Minutes, 1884–1899.

From John White, Secy., The Grange, Bolton Percy, England. Yorkshire Coach Horse Stud Book, Vol. VI.

From J. H. Pickrell, Secy., Springfield, Ill. American Shorthorn Herd Book, Vols. 41, 42, 43, 44.

From C. B. Thomas, Secy., Independence, Mo. American Hereford, Vol. 21.

From J. E. Rawlence, Secy., Salisbury, England. Hampshire Down Flock Book, Vol. 11, 1900.

From Mortimer Levering, Secy., LaFayette, Ind. American Shropshire Record, Vol. 13.

From W. A. Shafer, Middletown, Ohio. American Oxford Down Record, Vols. 6, 7.

From W. A. Brown, Driffield, Yorks, England. Leicester Flock Book, Vol. 8, 1900.

From James W. Taylor, Cheltenham, England. Cotswold Flock Book, Vols, 7, 8, 9.

From John Robson, Newton, Bellingham, England, Cheviot Sheep Flock Book, Vol, 9, 1900,

From Joseph E. Wing, Secy., Mechanicsburg, Ohio. Continental Dorset Club Record, Vol. 1.

From F. H. Ensor, Secy., Dorset, England. Dorset Horn Sheep Breed ers' Assn., Vols. 1, 2, 3, 4, 5, 6, 9.

From J. H. Miller, Secy., Elmore, Ohio. American Polled Durham Herd Book, Vol. 1.

From John Risden, Jr., Secy., Golsoncott, Washford, England. Davy's Devon Herd Book, Vol. 23, 1900.

From Fred Smith, Secy., Warren Hill, Woodbridge, England. Suffolk Stud Book, Vols. 11 (1898), 12 (1900).

From Ernest Prentice, Secy., 64 Oxford St., Ipswich, England. Suffolk Sheep Society Flock Book, Vol. 14, 1900.

From Ernest Prentice, Secy., Ipswich, England. Large Black Pig Book, Vol. 1, 1899.

From John Parr, Secy., Leicester, England. National Pig Breeders' Assn., Vol. 16, 1900.

From Heber Humphrey, Secy., Shippon, Abingdon, England. British Berkshire Herd Book, Vol. 16.

From W. Arthur Dew, Secy., Bangor, Wales. North Wales Black Cattle Herd Book, Vol. 6.

From F. L. Houghton, Secy., Brattleboro, Vt. Holstein-Friesian Herd Book, Vols. 17, 18.

FINANCIAL STATEMENT.

The Wisconsin Agricultural Experiment Station, in account with the United States appropriation.

1899-1900.	Dr.	Cr.
To receipts from treasurer of the United States as per appropriation for the year ending June 30th, 1900, under act of congress, approved March 2d, 1887	$15,000 00	
By salaries		$9,947 00
By labor		3,202 32
By publications		
By postage and stationery		
By freight and express		
By heat, light and water		
By chemical supplies		64 43
By seeds, plants and sundry supplies		770 14
By fertilizers		5 54
By feeding stuffs		57 40
By library		533 45
By tools, implements and machinery		81 00
By furniture and fixtures		35 00
By scientific apparatus		108 22
By live stock		40 00
By traveling expenses		155 50
By contingent expenses		
By building and repairs		
	$15,000 00	$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Wisconsin Agricultural Experiment Station for the fiscal year ending June 30, 1900; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file and have been by us examined and found correct.

And we further certify that the expenditures have been solely for the purposes set forth in the act of congress approved March 2, 1887.

(Signed) B. J. STEVENS,
WILLIAM F. VILAS,
Executive Committee.

ATTEST:
E. F. RILEY,
Custodian.

INDEX.

NOTE.—Page numbers refer to pages of this report; subject matter in bulletins published during the fiscal year are also included in this index, reference to the same being made by giving the number of bulletin prefixed by B.

Date Loaned